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# DEPENDABILITY PROGRAM PLAN

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93138

THEON COMPANY

SIGNAL DIVISION

(1)

(6) AN/BQQ-1 ( ) DEPENDABILITY PROGRAM PLAN

FISCAL Year 19 65 BUY

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## REVISION SHEET

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## INTRODUCTION

### GENERAL

This Dependability Program Plan is submitted in accordance with the requirements of Para. 3.2.28.3 of the Dependability Supplement to Appendix II dated 14 Jan. 1965. Appendix II is a part of Amendment 4, to MIL-S-22974 (SHIPS) dated 14 August 1964. The organization of the plan follows closely the individual paragraph headings of the Dependability Supplement.

The BQQ-1 ( ) Sonar System is used for the detection and tracking of enemy submarines. The system employs both active echo ranging and passive listening techniques, and has considerable operational flexibility, utilizing many different methods for obtaining target information. There are five recognized modes of operation within the concept of this Dependability Plan.

These are:

(1) Passive Detection,

(2) Passive Tracking,

(3) Passive Localization,

(4) Active Localization, and

(5) Active Detection and Tracking.

Each of these modes has a specified probability of success associated with a given mission time. Assuming an exponential distribution of times to failure, the mode requirements have been calculated in terms of MTBF. A minimum equipment repair time has also been specified for this equipment and Maintainability prediction and analysis efforts are intended to assure achievement of this repair time.

The dependability program for BQQ-1 Systems purchased under Contract NObsr 93138 ('65 Buy) represents a carefully planned, integrated series of tasks initiated at the early stages of system study and analysis and carried forward throughout the design, development, manufacture and test phases. (See Figure 1.) Since the BQS-6 is a highly redundant multi-moded, repairable system, some degree of downtime is permissible and hence achievement of a high dependability or availability becomes of vital importance. The attainment and successful demonstration of the two factors which comprise the system Availability parameter, i.e., Reliability (MTBF) and Maintainability (MTTR or ERT), are the primary objectives of this program plan.

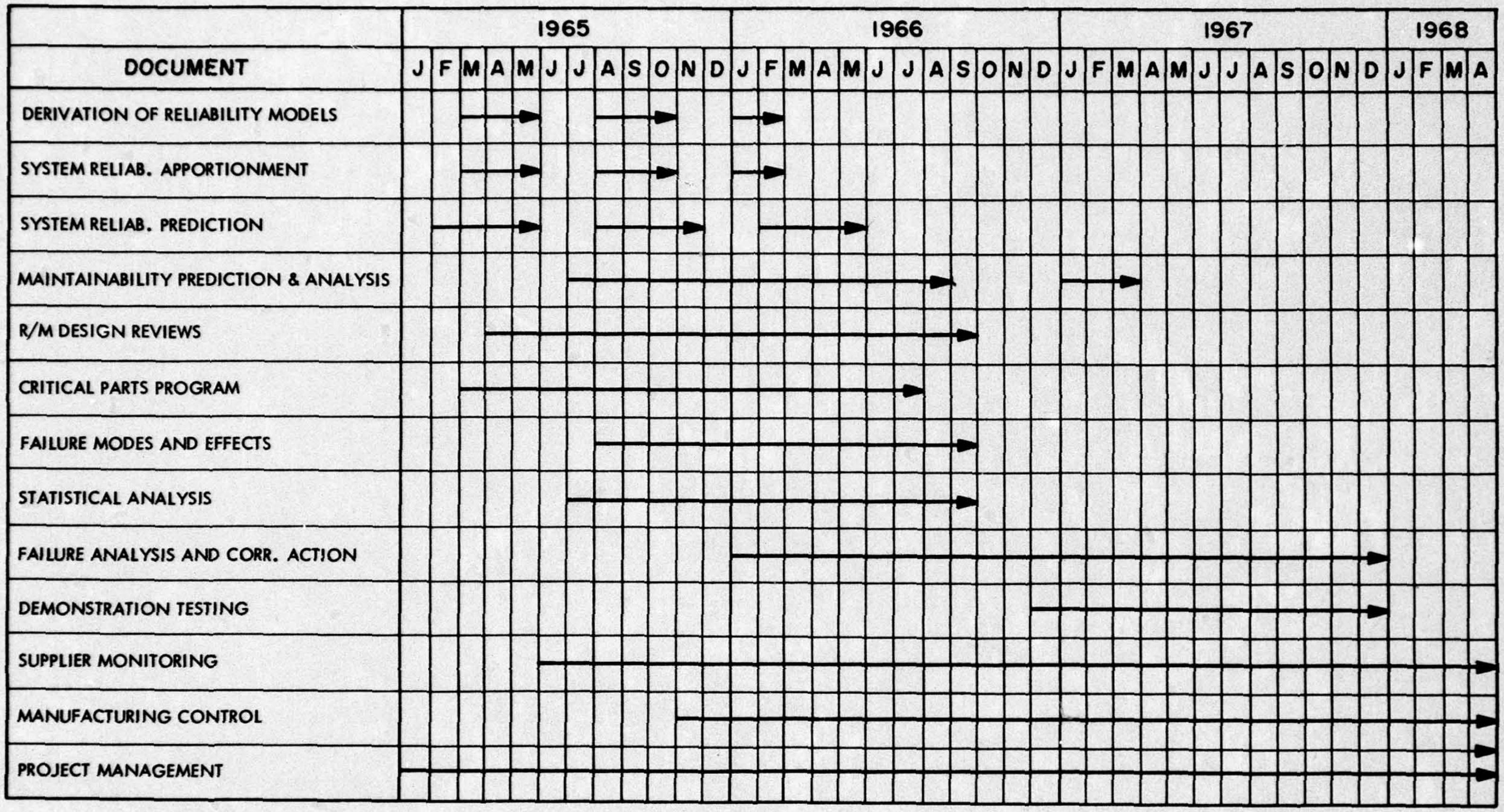


FIGURE 1 TIME-PHASED DEPENDABILITY PROGRAM ELEMENTS

## a. ORGANIZATION AND MANAGEMENT

### Organization

The Raytheon Sub Sig Division R/M organization operates under the charter of the Product Assurance Function which in the same manner as the Engineering and Manufacturing functions, reports directly to the Division General Manager. Figure 1 indicates these relationships.

It can be noted from Figure 1 that the R/M Department, together with the various Quality Control Departments, is at the same organizational level as Systems Engineering, Design Engineering, Purchasing and Industrial Engineering. In this way the Product Assurance Departments have organizational stature commensurate with their responsibilities and impact on the design and production of the hardware.

The functions and responsibilities of the various Product Assurance Departments are shown in Figure 2. As it can be seen there are five departments reporting to Product Assurance, each having specific duties and responsibilities for the accomplishment of the Product Assurance function.

One of the five Departments is Quality Control. Two groups report to the Manager of Quality Control;the Inspection/Test group and the Quality Control Engineering group. Between them, these groups control the quality of all in-house manufacturing activity.

The Inspection/Test Department has the responsibility of assessing the quality of all material manufactured/assembled in-house, both in process and on through final test, final inspection, packing and shipping. This assessment includes checks on workmanship, function, conformance to latest document revision incorporation and compliance with applicable engineering/government specifications. It is also the responsibility of the Inspection/Test Department to maintain accurate and up-to-date records of its activities and to report information on quality to Production and Quality Control in order that quality analyses can be made and corrective action implemented where its need is indicated. The detailed, formal, routine activities of the Inspection/Test Department

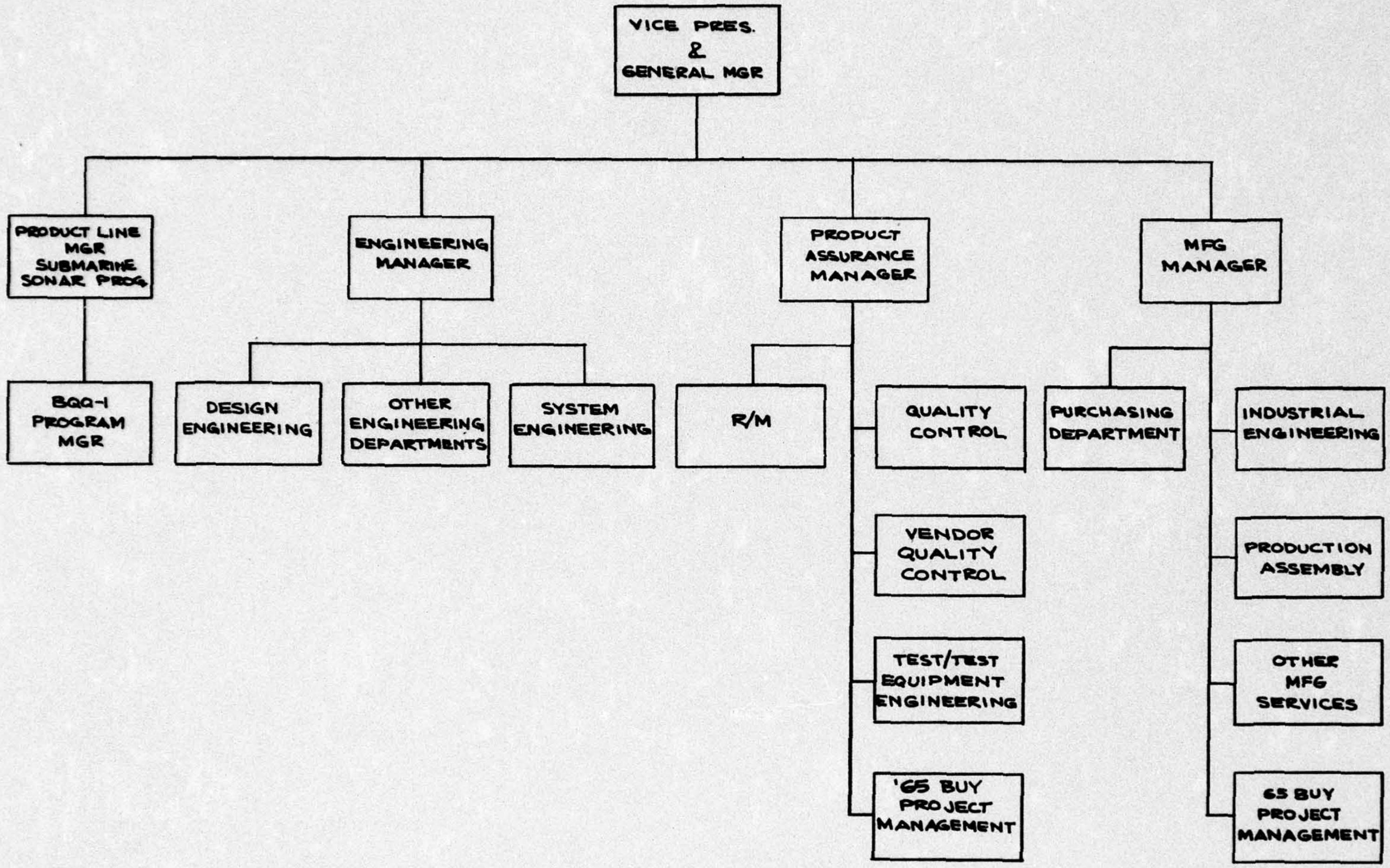


FIGURE 1 ORGANIZATIONAL/FUNCTIONAL RELATIONSHIPS

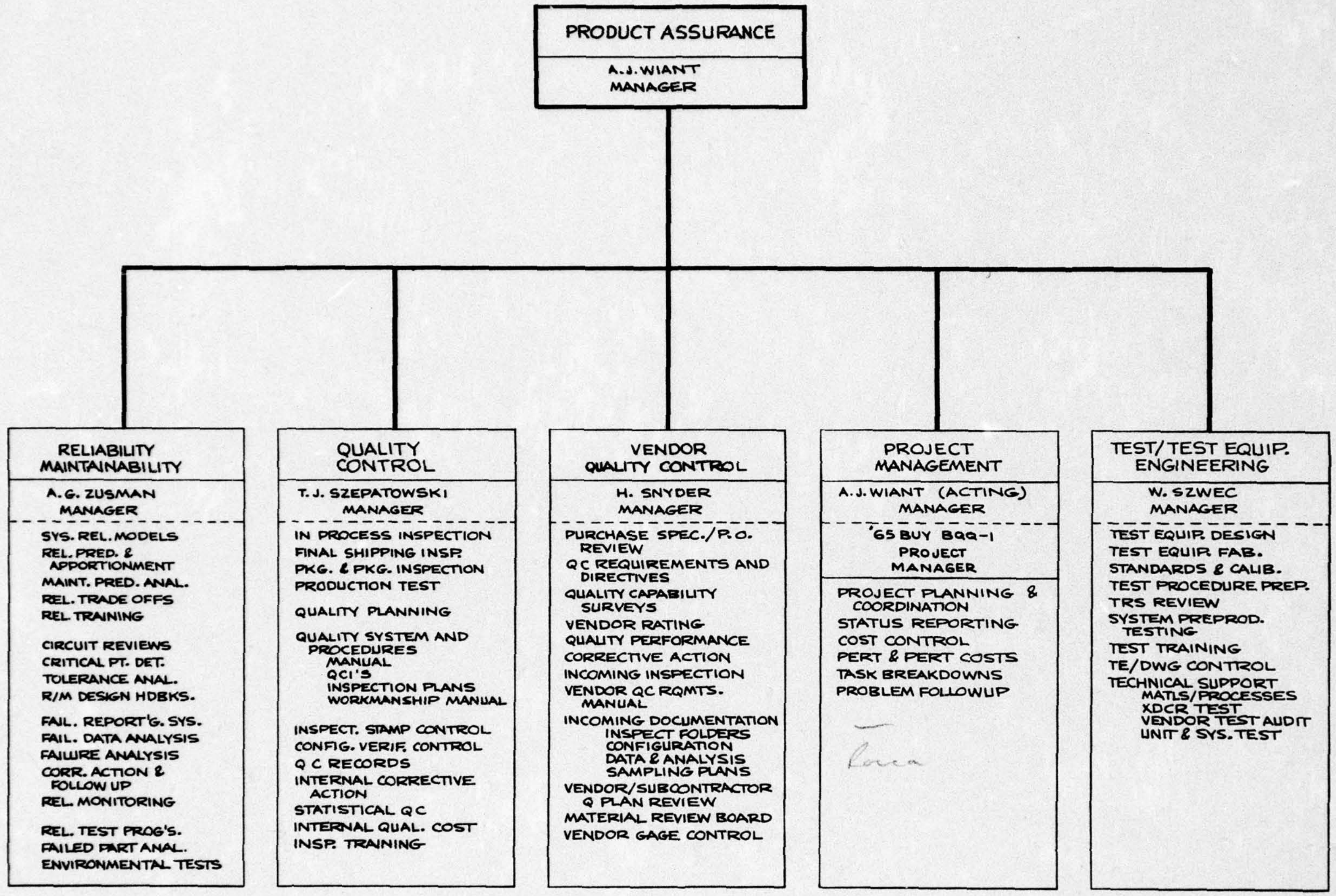


FIGURE 2 PRODUCT ASSURANCE ORGANIZATION

are governed by written procedures prepared, issued, controlled and revised by the Quality Control Engineering group as described in the Quality Assurance Manual.

The Quality Control Engineering Group, besides being responsible for the procedures which govern the activities of the Inspection/Test Department, has several other responsibilities. It prepares, issues, controls and revises the procedures and policies followed by all the activities under the Product Assurance Function, except those for the Reliability/Maintainability Department. It maintains the official records of all inspections and tests, internal corrective action activities, quality costs of all Product Assurance functions and is responsible for the estimates of quality costs for proposals. Through the use of statistical analysis, the Q. C. Engineering group determines the extent of in-house inspection activities. By close cooperation with other departments, it analyzes the impact of quality requirements in contracts and through additions to and revision of the Quality Control Manual, Quality Control Instructions, the Workmanship and Standards Manual and Test Method/Inspection Procedures, assures that these requirements are met where applicable.

The Vendor Quality Control Department is responsible for quality on all purchased material from vendors and sub-contractors. The responsibilities of the Department begin with the review of specifications on parts to insure the inclusion of proper inspection and quality safeguards in the purchase orders. The Department also conducts quality capability surveys on both proposed and existing vendors for conformance to applicable contractual and Government requirements. It is responsible for product inspection at Incoming, review of all defective material for corrective action and assurance that the vendors take effective action to eliminate defects. The Material Review Crib and Tool and Gage Control are also a part of this Department in order that integration of these related functions will contribute to the over-all Quality Plan for the adequate surveillance of incoming material with maximum quality cost effectiveness.

The Test/Test Equipment Engineering Department is basically responsible for providing the test procedures and test equipment in support of the test program carried on by the Inspection and Test Department. These test procedures and test equipment are based on contract and specification requirements as assigned by Engineering to the various sub-assemblies and units. Unit Test requirements are reviewed for compatibility with the specification as well as the test procedure preparations. This department is also responsible for materials and process control, vendor subcontractor test plan approval, test audit and technical support to materials/processes, transducer test, vendor test audit and unit and system test. Also, since it is Division policy to procure material and calibrate all test equipment used in the design and manufacturing processes, the test equipment calibration and maintenance activity is also a responsibility of this Department.

The Project Management Department is responsible for the overall planning scheduling coordination and direction of Product Assurance function pertaining to Production and/or Engineering Programs. A Product Assurance Project Manager is assigned to each Engineering and/or Production Program who acts with the full authority of the Product Assurance Manager on the program. He is responsible for cost control, PERT scheduling, task breakdowns, customer liaison and must remain alert to new requirements or developments so that timely notification can be made to assigned personnel.

The R/M Department under Division Policy and Procedure No. E8.014 is responsible for the conduct, direction and management of all R/M programs undertaken by the Division. The Department consists basically of six functional sections. These sections and the types of R/M efforts performed by each are discussed in the following paragraphs. In addition to the functional groups on R/M project engineer is assigned to each major program with the responsibility for overall program planning and scheduling, inter-department coordination, PERT charts, schedules and budgets.

The project engineer will issue work statements as required to the various functional groups for the performance of the required effort. Each reliability project engineer is responsible for the R/M efforts pertaining to his project. Personnel assigned to a particular project are responsible for their technical performance to the project engineer although administrative responsibility is retained in the individual functional groups. In this manner each functional group can grow in technical sophistication along its individual speciality and since one function may be involved with several projects each project can benefit from the continually increasing knowledge and experience.

The R/M Statistical Analysis Section is responsible for statistical studies pertaining to reliability, maintainability, availability, etc. In addition this section develops special computer programs for various mathematical modes and procedures. They provide statistical assistance in the design of experiments and analysis of data and engage in R/M research programs as required. In the FY '65 Buy program this group will be responsible for analysis of reliability models, performance of system prediction, design of special part tests and analyses of test data.

The Systems/Design Support Section is responsible for providing R/M information to system engineers and designers. In the '65 Buy program this group will be responsible for product identification, system failure mode and effect analysis, system interface considerations, concept reviews, electrical and mechanical design reviews, and statistical circuit analyses.

The Component Application Section is responsible for part testing and qualification programs, reviews of electrical and mechanical part purchase specifications, assisting designers in selection and application of parts, assisting in selection in vendors and maintenance of parts standards. In the '65 Buy program this group will be implementing all of the above efforts to assure a high degree of parts and materials control.

The Reliability Testing Section is responsible for performance of Component Testing Programs including analysis of failed parts and operation of the Environmental Test Facility. On this program they will be responsible for performance of critical parts tests and engineering evaluation tests (environmental) of sub-assemblies and assemblies. During reliability demonstration tests they will assist in setting up the system for the vibration environment.

The Product Support Section is responsible for performance of failure analysis of inplant and field failures to determine cause and initiate suitable corrective action where required. The Section also sets up special procedures for failure data collection and reporting and conducts indoctrination lectures on failure reporting for maintenance technicians in the field. This Section has been responsible for the effort performed on Contract NObsr 91276 and will perform the in-plant failure analysis on the equipments being built on NObsr 93138.

The Maintainability/Human Factors Section performs maintainability prediction analyses on equipment in accordance with MIL-M-23313A and reviews equipment designs for maintainability factors. The Section also provides Human Factors consultation with Systems Engineering in the design of operator consoles and assures proper consideration of man-machine interfaces in all phases of the equipment design. In the '65 Buy Program, the Section will be responsible for the maintainability prediction and demonstrate test procedure and will provide an input to the design reviews in the areas of maintainability and human factors.

Management Control of Program

Since the overall BQQ-1 ( ) Dependability Program involves many activities other than R and M such as manufacturing control, subcontractor and vendor control and configuration control. All of the Product Assurance functions are responsible in some manner for a part of these efforts. For this reason a Product Assurance Project Manager (Dependability Program Manager) will be assigned to coordinate the efforts of all Product Assurance Departments and assure that work is on schedule, problems are resolved satisfactorily and funds are being spent judiciously.

The Product Assurance Project Manager will be a key member of the Program Manager's team representing the total Product Assurance Function. He will report directly to the Product Assurance Manager and will receive management direction and support from him. He will have the full authority of the Product Assurance Manager in resolving BQS-6 ( ) program problems and in coordinating the efforts of all the Product Assurance Departments. He will participate in all Program Team conferences and will work closely with the Engineering and Manufacturing team members.

The Product Assurance Project Manager will have his own team of assistants consisting of project engineers appointed from the various departments within Product Assurance. Meetings will be held regularly between the Product Assurance Project Engineers and the Product Assurance Project Manager to assure that he is kept completely informed of program progress within the Product Assurance function.

The R/M Project Engineer will work closely with the Product Assurance Project Manager making sure that he is kept up-to-date on progress of the R/M activities. The R/M Project Engineer will have the responsibility for defining the R and M tasks necessary to assure compliance with the contractual requirements. He will monitor the performance of these tasks and evaluate their adequacy, receiving advice and assistance as required from the R/M Department Manager. Periodic status reports will be required for all major activities and where necessary special forms will be devised to indicate the level of current progress and percent of completion. This will enable the R/M Project Engineer to recognize potential schedule slippage rapidly and apply corrective action as required. R/M milestone charts indicating the required time phasing of each activity will be used to assure proper coordination of efforts and anticipate potential workload or staffing problems. In addition the entire R/M program will be included in a PERT program so that key events can be scheduled and monitored. Regular conferences will be held with all activity group leaders to determine potential program bottlenecks, assure adequate communication between activities, and expose areas where additional management controls must be placed.

The R/M Project Engineer will be on the distribution list of all system and project memos and design documentation including system and unit specifications and design memos. During the development phase the R/M Project Engineer will be the focal point for coordination of the various Engineering Departments with the Manufacturing and Quality Control team members so that rapid corrective actions can be brought to bear on production problems. These meetings will also assure that the Failure Analysis program is in receipt of the latest information. In this area in particular, the R/M Project Engineer will coordinate his effort closely with the Product Assurance Project Manager to assure the rapid resolution of quality or reliability problem areas.

## b. RELIABILITY DESIGN

### 1. Techniques

Since inherent reliability is design-limited, a thorough comprehensive effort is planned to assure that designs are adequate and will meet reliability requirements. Figure 1 indicates how the reliability activities will be coordinated throughout all phases of development, production and test. During the system analysis phase, R/M engineers will perform system complexity studies; derive mode reliability models; perform various reliability and maintainability trade-offs, analyses, and analyze mode reliability. R/M Engineers will work directly with Systems engineers, assisting them in utilizing redundancy techniques, indicating preliminary failure rates of units, calculating preliminary mode MTBF's and assuring that each mode of operation will achieve its reliability requirement. As the systems phase of analysis progresses into unit specifications, R/M engineers will apportion system MTBF requirements to the lowest sub-assembly levels. These apportionments will be included in the unit specifications presented to designers. At this time also, from analyses of the reliability models, those units or parts whose failure could cause loss of an entire mode of operation will become evident and will become the basis for special reliability controls used to assure their proper performance. These special controls are discussed in paragraph 3 under the Critical Parts Program.

During the Electrical and Mechanical design phases of the equipment, independent design reviews will be conducted by experienced Reliability personnel. Such reviews will include comprehensive investigations of electrical and mechanical designs for satisfactory part selection and application, adequate part deratings, environmental resistance, satisfactory thermal design, etc. A detailed discussion of the design review program is presented further on in this plan. Coincident with

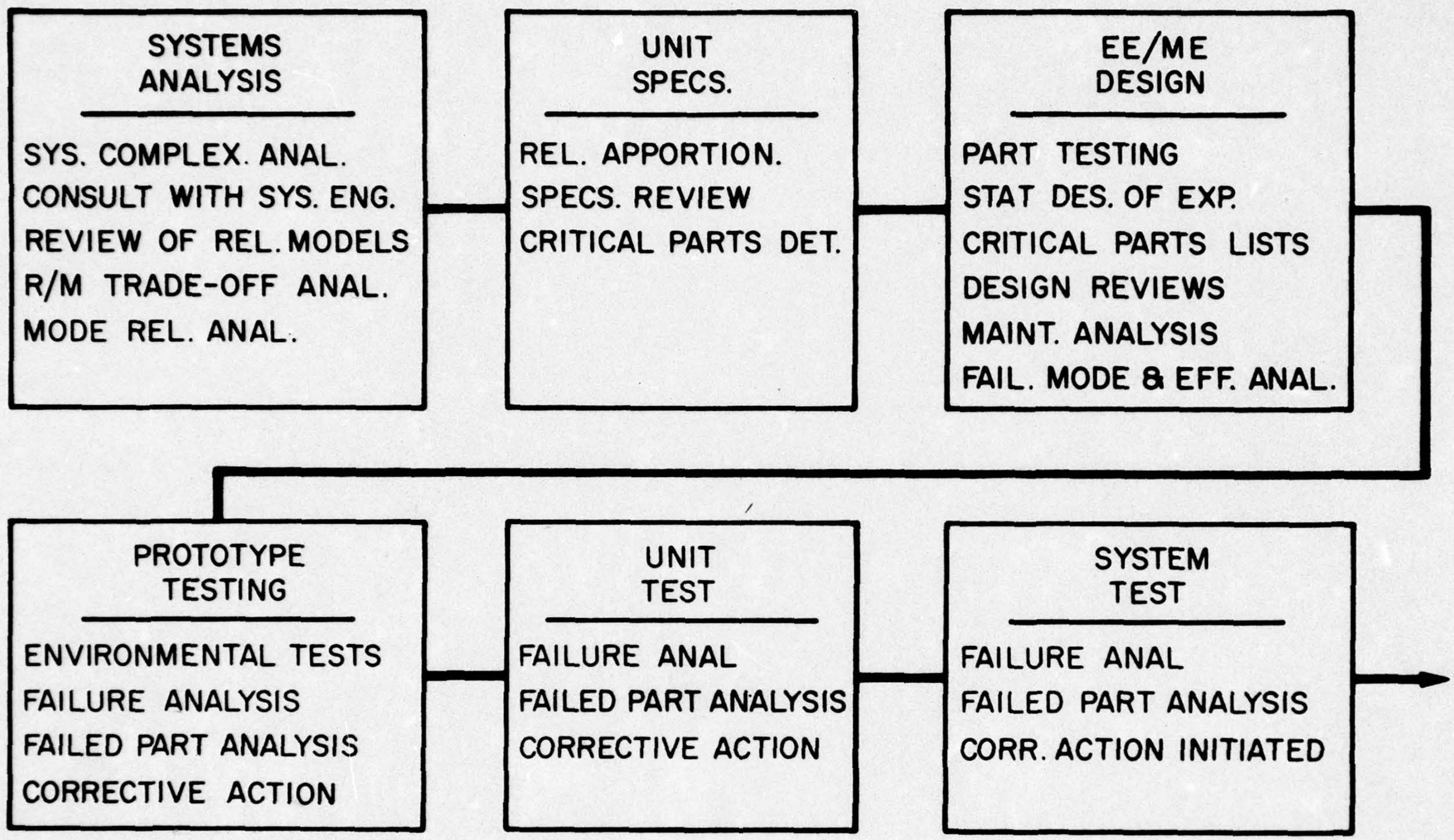


FIGURE 1 R/M PROGRAM COORDINATION

the design review will be a maintainability review of design from the standpoint of adequacy of fault location and isolation, accessibility and personnel safety hazards. At the same time also a failure mode and effects analysis will be conducted to determine areas of extensive secondary part failure, to develop improved means for fault isolation and location, and to assist in highlighting critical parts and assemblies. Critical parts lists will be derived, and special parts tests will be performed using statistical experiments to assure maximum receipt of data from part tests. During the prototype testing phase (service test model) information from environmental tests will be used as inputs to an extensive failure analysis and corrective action program described in detail in a later section of this plan. At unit and system tests also, failure data will be collected and analyzed and used as results inputs to the failure analysis program. Corrective actions will be initiated through the issuance of Engineering Changes thereby assuring a steady process of reliability growth.

2. Design Analysis

Circuits will be analyzed for performance at the extremes of environment as well as for anticipated variations in part tolerances due to manufacturing processes. These analyses will be assisted by computer programs such as the IBM Electronic Component Analysis Program(ECAP), especially for those circuits that are critical in their application in the system.

Where part applications and/or circuit designs appear marginal or inadequate, immediate corrective action will be instituted. Since the independent R/M design review effort will be conducted early in the design phase, only a recommendation to the circuit designer will be required to institute the necessary changes. A similar analysis effort will be conducted on the mechanical designs. The speed and economy of incorporating the recommended changes prior to design release will be a major advantage of this effort.

3. Critical Parts Program

An integral part of Reliability and Maintainability Analysis is the acquisition of failure rate information relating to component parts and the assurance of the reliable application of these parts in the required function. An all-encompassing parts testing program would require large expenditures of time and effort much beyond the requirements of a repairable system such as the BQS - 6 ( ). Therefore, a trade-off in effort appears to be necessary. Only those parts deemed "critical' (following a system functional analysis) will be subjected to close Reliability/ Maintainability surveillance, part testing and/or evaluation.

a) Critical Parts

Parts will be deemed critical based on one or more of the following criteria:

1) The part failure would result in loss of a major operational mode as defined in the Dependability Supplement, unless the part has a history of proven reliability and quality.

2) The part is a high population item used extensively throughout the system and because of its widespread application must be reliable except for parts ( and the manufacturers) having a history of known reliability and quality.

3) Non-standard parts or parts where little or no previous knowledge exists regarding their reliability potential and where failure of the part results in loss of a major operational mode.

4) Parts which require special handling, special material, special processes and/or special manufacturing techniques.

b) Procedures and Controls for Parts Classified as Critical

Once parts have been classified as "critical" the following controls and procedures will be implemented.

1. Non-Standard Parts

a) Part Specifications

Part specifications will be prepared to insure maximum quality, minimum failure rates and to highlight critical parameters. All specifications drawings, including vendor selections, will be reviewed and approved by R/M.

b) Qualification Data

Specifications drawings will stipulate that part qualification data will be submitted with the first production sample. Continuous surveillance of the vendor's production will be maintained by Vendor Quality Control with R/M support in Reliability problem areas. 100% inspection and testing of critical parameters will be instituted where required to maintain quality and high part reliability. This will be performed at either the vendor's plant or in-plant by Raytheon.

c) Vendor Surveillance

Raytheon Vendor Q.C. will perform quality surveillance of the vendors (where necessary) to determine vendor qualifications in areas of Q.C. procedures, instrumentation, calibration, test facilities and control, and other pertinent areas to assure high quality parts on a continuing basis.

d) Special Testing

Where necessary, special tests will be designed and performed to assist in determining part reliability and potential modes of failures. The type of test performed will be based on part type but examples of tests that could be used are life testing, accelerated stress tests IR scanning techniques.

2. Standard or Mil Type Parts

a) Vendor Control and Selection

Because of wide parameter variations from vendor to vendor of MIL or STANDARD parts (particularly in the semiconductor area), tests will be performed on vendors of a particular part QPL so that critical part parameter variations can be minimized. Vendors will then be selected from the QPL, based on the outcome of the test results.

b) Incoming Part Testing and Inspection

In order to maintain the critical part parameters at minimum variations, incoming testing of these parameters will be performed at a 100% level or reduced sampling as the lot size dictates.

Critical Assemblies

A critical assembly is defined as an assembly whose failures would result in loss of a major operational mode as defined in the Dependability Supplement. An assembly may be denoted as critical whether it does or does not contain critical parts. For example an assembly composed entirely of MIL STD transistors, resistors and capacitors will not have critical parts but may be denoted as a critical assembly depending on its function in the system. An assembly containing a critical part usually will be a critical assembly except in the special case where failure of the part would not cause failure of the assembly.

All assemblies denoted as critical shall be subject to the following tests prior to installation into cabinets:

The assembly shall be subjected to a successive vibration and temperature-cycling environment. Vibration shall be performed for one (1) hour in each of the three orthogonal planes, in accordance with MIL-STD-167 at a frequency of 28±2 cps with a double amplitude excursion of 0.010 inches. The assembly shall then be placed into an environmental chamber and the temperature of the chamber shall be lowered to -54 + 3, -1°C. Electrical power shall then be applied and the assembly shall remain at this chamber temperature for 30 ± 5 minutes. At the end of this period, the temperature of the chamber shall be raised to +65°C and the assembly shall remain exposed to this temperature for a minimum period of 3 hours. At the end of this period the chamber temperature shall be lowered to 25±3°C and all specified electrical tests shall be performed.

4. Vibration and Shock Testing Program

A program of environmental testing on the sub-assembly level will be incorporated during the design phase as follows:

a) Approximately sixty (60) percent of the subassemblies for the system will be subjected to exploratory shock and vibration.

b) The vibration will be along each of three axes in the frequency range of from 5 to 50 cps to determine if resonances are present.

c) The shock test will consist of one (1) drop test on each subassembly, using a Barry Drop Test machine and a 25-30 cps fixture.

d) Photographs will be taken using high speed cameras to record the subassembly motion under shock.

5. Design Guides

Design guides such as NAVSHIPS 94501 will be utilized to a maximum degree, both by R/M Department and Design Engineers. This will have a dual advantage; standardization of technique and a common reference for discussion. An R/M Design Engineering Manual will be provided to all designers which will stress these areas of design peculiar to the AN/BQQ-1 Sonar System. In addition to the general reliability and maintainability information found in most handbooks, the R/M Manual will present to the design engineer the information he will require to design his particular circuit, such as: the reliability requirements, the maitinatinability requirements, the environmental considerations, critical parts considerations, etc. This R/M Design Engineering Manual will be distributed to each Design Engineer in the AN/BQQ-1 Program. It will provide a convenient reference for any technical considerations peculiar to this program.

6. <u>Signatory Authority</u>

<u>The Dependability Organization will have Signatory Authority on the Following Documents</u>:

a) Part Specifications

b) Study Layout Mechanical Drawings

c) Preliminary Schematics and Parts Lists

d) Detail Mechanical Drawings

e) Final Production Drawings, prior to release to Manufacturing

f) Engineering Change Orders

g g) Drafting Change Orders

h) Production Change Orders

By use of this sign-off authority, each drawing will be reviewed by R/M Department prior to issuance for its impact on the equipment reliability.

## c. MAINTAINABILITY DESIGN - PROGRAM PLAN

### 1. Techniques

In achieving a high degree of Maintainability in the BQQ-1 Sonar system, it is of prime importance that the occasion for maintenance action be reduced to a minimum through the extension of the mean-time-between-failure (MTBF). When maintenance is necessary, however, it is essential that system design provide for rapid system recovery by reducing the repair time to a minimum, with particular emphasis being exerted in those areas where part failure criticality affects the system mission.

Fault localization will be achieved through the use of a Central Maintenance System (CMS) whereby failures can be localized to various functional levels. within the system from a central point. Wherever practical, failures will be isolated by CMS to a replaceable assembly or part. Isolation of a failed part or assembly will be facilitated by careful location of test points, functional grouping, and by simplified trouble-shooting instructions, circuit diagrams, or other pertinent information, provided to the technicians by the CMS film viewer display.

Modularization is used throughout the system as a means of assuring rapid system recovery in the event of failure. In addition, multiple redundancy is used extensively to assure a high degree of system tolerance to part failure without aborting the system mission.

In the prediction and analysis of maintainability design data, procedures provided in MIL-M-23313A and in NAVSHIPS 94324 will be utilized.

Formal and informal design reviews are conducted throughout all phases of design. Close coordination with reliability, systems, and engineering personnel is maintained. In addition, the development of design guides, maintainability check-lists, and similar techniques will also be utilized to improve system maintainability during design. Requirements for MTTR are also included in system and unit specifications.

2. Design Analysis

When drawings, schematics, design layouts, or other design data are submitted to the R/M Department for review, a thorough examination of the proposed design is made by competent personnel in terms of maintainability requirements. Improvements are then discussed with cognizant designers at regular design review meetings at which maintainability is always represented.

Every effort is made to coordinate activities with designers before proposed design requirements and hardware configurations become firm, in order to incorporate maintainability design improvements as early as possible.

3. Design Guides

An AN/BQQ-1 Reliability and Maintainability Engineering Manual has been prepared as a means of providing all design engineers and others with a convenient reference of maintainability design guides and other useful reference material. This handbook provides the designer with information specifically oriented toward the requirements of an AN/BQQ-1 Sonar System, and contains maintainability prediction techniques, maintainability check-lists, policy and procedures as they relate to maintainability as well as other pertinent information relating to maintainability design practices. Copies of 94324 are being distributed to all design groups.

4. Human Factors

Human Factors engineering is considered to be an integral part of the maintainability program. It is the function of the human factors program to provide requirements and the criteria to insure that the equipment will best utilize human capabilities in its operation and maintenance; to determine the human performance required to maintain and monitor the system; and to provide recommendations for any special training required of maintenance personnel.

In order to accomplish the above objectives, the Human Factors program will consist of the following

a: Equipment Design Review:

Human factors will participate in the design review and evaluate station and panel layouts., operating consoles, and assorted displays to insure that functions and tasks assigned to the man-equipment interface can be performed adequately. Recommendations for the arrangements of controls, indicators displays and adequate access will be provided to minimize maintenance downtime. A maintainability check list has been developed to aid in accomplishing this function.

b. Work Area Evaluation.

Floor plans will be reviewed to determine that the arrangement of equipment and the environmental conditions are consistant with the functional requirements of the man-machine interface in terms of general comfort, safety, ease of maintenance and performance proficiency. This will indlude the establishment of requirements for access, safety, ambient lighting: ambient noise, ventilation and visibility of displays.

c. Trouble shooting procedures.

Human factors will work closely with Systems Engineering and System Services to establish trouble shooting procedures for incorporation into the CMS console. This procedures will be based upon the analysis of the operating modes and the Failure Modes and Effects Analysis.

d. Training Requirements.

Human factors will provide requirements for navy maintenance personnel based upon the analysis of the equipment and maintenance requirements. The purpose of this training recommedation will be to provide a means for reducing the time required to locate and violate malfunctions.

5. Elimination of Adjustment

The elimination or minimization of adjustments considered to be of paramount importance in the development of a system with superior maintainability characteristics. It has long been recognized that adjustments in electronic equipment often reflect circuit instability with a consequent degradation in system operation. The need for adjustment is being minimized by careful design and analysis to assure circuit stability, and by effective control of all system adjustments which are deemed necessary to normal system operation.

To implement this control system specifications stipulate that adjustments will be permitted only where essential to meet operational requirements, and then only with prior approval of Systems Engineering.

6. Specification and Drawing Sign-Off

Maintainability procedures and responsibilities for the sign-off of specification and drawings is described under the Reliability section.

7. Central Maintenance System

One of the most significant design features of the System in achieving a high degree of maintainability is the incorporation of the Central Maintenance System (CMS). The impact of the CMS in accelerating repair time is most effective in several areas. Besides the obvious improvement in fault localization and isolation, significant benefits occur from the centralization and the simplification of the primary failure analysis function. In addition, it provides step-by-step procedures for localizing the failure to a unit or sub-unit, and in some cases to the replaceable part or module.

Simplified trouble-shooting instructions are also provided to the technician by the integrated film reviewer obviating the need for cumbersome test equipment, maintenance manuals, and schematics to be used in the limited confines of the sonar equipment areas.

Particular attention is paid to the human factor features of CMS in order to make it compatible with the limitations and capabilitites of the maintenance technicians who will perform the maintenance function.

8. Repair Philosophy

The repair philosophy of the AN/BQS-6 ( ) system considers that it is most important to reduce the occasion for maintenance by designing into the system the capability to tolerate a large number of part failures without suffering critical system degradation.

This failure tolerance is achieved by means of extensive redundancy in transducer paths, the modular drivers, as well as duplication of functional capabilities in certain modes of operation.

Modular construction and plug-in printed circuit boards are used extensively as a means of reducing repair time to a minimum. Test points are carefully placed at all points in the system where trouble-shooting is required as a means of reducing isolation time to a minimum. Rapid localization of a malfunction is accomplished by means of a Central Maintenance System which will localize failure to the lowest practical level within each unit.

Consideration of repair philosophy must account for all factors which significantly affect the repair cycle or result in system downtime. Particular effort is being directed toward identifying critical part failures in order to take appropriate corrective action in the form of improved reliability and repair capability. Similarly, logistical influences, such as spare parts provisioning, are also given consideration. As a consequence, it will be necessary to provide at least one spare for each type of printed circuit board which is a replaceable item.

## d. FAILURE MODES AND EFFECTS ANALYSIS PLAN

### 1.0 APPROACH

Equipment Dependability is recognized as a system concept. The Failure Mode and Effects Analyses must relate to the System Effectiveness through the equipment configuration levels down to the individual component piece part. Within the program time constraints identification of Critical Areas and the effective implementation of adequate corrective action, where required, is mandatory. Therefore, the failure modes and effects analysis objectives are as follows:

a) At the system level, the effects of unit primary failure on system operating modes are analyzed to determine which units are critical. The commonality chart and the reliability models are used in this analysis to identify those units whose failure would cause the most serious effects on system operation. "Critical" units thus identified are studied to find ways to reduce the frequency of failure and to reduce the effect of failure on system operation. This analysis progressively includes lower levels of assembly.

b) A second analysis determines the nature of secondary failures, resulting from the primary failures. Secondary failures in "critical" units can result from primary failures in "critical" or "non-critical" units and the effect on system operation will be as serious as a primary failure in a critical unit. Secondary failure modes are studied to determine ways of eliminating secondary failures or to reduce their effect on system operation in the various operating modes. This analysis progresses from the system level down through the replaceable sub-assembly level.

c) Lastly, critical failure modes are analyzed to determine what failure symptoms would be detectable by the operator, either through the operator's console or through the Central Maintenance System. Early correction of critical failures requires immediate detection of the occurrence of the failure. This analysis results in recommendations for continuous monitoring points and test points.

## 2.0 APPLICATION

Considering the AN/BQQ-1( ) system initally as an assembly of "Black Boxes ", it can be determined that the occurence of either of the basic catastrophic failure modes; (open or short), will reflect in one of three basic failure effects; (inoperative, degraded or no effect). Expanding the consideration through the equipment configuration levels to the lowest sub-assembly will highlight the critical levels for each operating mode. Analysis will consider the secondary effects of basic failure modes on the immediately adjacent levels of configuration. The results of this investigation will be reflected in the reliability apportionment and reliability and maintainability prediction updating.

Analyzing all equipment configuration levels will define the critical areas and critical parts within those areas. This analysis will result in a critical part test program to establish the part capability for the application. A corollary to the Failure Modes and Effects determination will be the projection of indicators of failure occurance available at the operator consoles. Interpretation of the effects of failure occurring in remote locations through the controls and presentations normally available to him will serve as a cross-reference for initial fault location. This approach will be developed in support of the equipment Maintainability effort. Tracing the failure modes and effects through the system will reflect in expediting "on board" fault identification, more rapid utilization of the Central Maintenance System and an earlier return to normal equipment operating capability.

The equipment performance specification and design concept will be reviewed for compatibility. The equipment Functional Block commonality chart will indicate commonality of sub-systems and units to the several operating modes and initial potentially critical function areas. As preliminary schematics and parts lists become available, these will be evaluated for most probable part failure modes, inclusion of special parts, state-of-the-art techniques and applications. An analysis of those areas which have critical part failure modes will be performed and a unit evaluation is prepared as an input to the preliminary design review panel. The evaluation will provide data for discussion of the noted part Failure Modes for which inadequate protection is provided, and will recommend courses of corrective action and indicate priorities on the basis of most critical part failure modes.

The units for which operating failure modes are determined will be analyzed through the sub-assembly, module and piece part levels to establish Failure Effects and their influence on the specific assembly and immediately adjacent functional levels. These effects will be tabulated and the tabulations maintained up-to-date to reflect the incorporation of engineering changes and corrective action recommendations.

In parallel with Critical Parts List generation, test procedures and programs for the determination of most probable failure modes and adequate safety margins for specific applications will be developed. The data and recommendations resulting from such programs will be made available to Design Engineering and reflected in up-dated Failure Mode and Effects tabulations (Figure 1). This process of unit assessment for the determination of Critical Areas, establishment of Failure Modes, analysis of Failure Effects and implementation of Corrective Action recommendations will be continuous throughout the equipment design and development phase.

FM & EA CHART

| ITEM | FAILURE MODE | SECONDARY EFFECTS | CONSOLE INDICATION | OPERATING MODES | REMARKS |
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FIGURE 1 FAILURE MODE AND EFFECTS ANALYSIS CHART

The FM & E analysis will be continued through the equipment production engineering and assembly to detect, review and correct production processes and techniques which are considered to degrade the inherent equipment dependability.

## 3.0 CORRECTIVE ACTION TECHNIQUES

For the FM&E program the Critical Area is initally determined as a function of equipment and the operating modes. The Critical Unit can then be considered on the next lower level to identify the critical sub-assembly and by progressive analysis to the identification of the critical failure mode and the effects of such failure modes. Knowledge of the mechanics of failure provides background for the recommendation of appropriate corrective action. Throughout the period of the Program the definitization of Critical Areas and Parts will take into account the equipment system redundancy, substitution of standard for initially special parts and the elimination of critical parts or incorporation of measures which minimize the resultant detrimental effects.

## 4.0 APPLICATION TO PREDICTION

The result of the Failure Modes and Effects Analyses will be applied to the initial Dependability predictions as quantitative modifiers reflecting equipment function, operation and application. These results will highlight areas of criticality not revealed specifically by prediction on the basis of stress-assessed part failure rates. The determination of such failure rates accepts the random failure rate index for a specific part type as an irreducible minimum for a given stress ratio.

## 5.0 PERIODIC UPDATING

The achievement of satisfactory operational equipment dependability is a function of the inherent reliability and maintainability the manufacturing processes and the operational utilization. Throughout the equipment Design and Development phase potential production problem areas will be noted and recorded for consideration by Production Engineering and Quality Assurance. Data derived from Failure Modes and Effects analyses, Reliability system apportionment and Critical Parts test programs will be reflected in the Dependability Demonstration Test Specification and Procedure. The findings of the progressive analyses will be made available as:

Inputs to the Design Review Panels.

Correlation data to Reliability Predictions.

An aid to the adequate definition of part stress Safety Margins.

An aid to definition of Vendor controls.

A determining factor for Critical Parts test programming.

An aid to the determination of Preventive Maintenance Procedures and Schedules.

In line with the intent of this plan, status reports, advisory reports and recommendations for corrective action, will be prepared and submitted as necessary throughout the program.

## e. RELIABILITY APPORTIONMENT

### 1. Determination of Operational Modes

The AN/BQQ-1 Integrated Sonar System requirements for reliability are derived from the contractual specifications. These define the performance requirements for each operating mode and are usually derived from the Ship's Operating Requirements (SOR). The System requirements will be reviewed and a reliability block diagram will be generated for each operational mode. The mode reliability requirements will then be apportioned into reliability requirements for each block. The apportionment is done on the basis of expected equipment failure rate, criticality and previous experience. A mathematical model will be derived for the model configuration to determine if the apportioned reliability for each block in combination will provide the required reliability. Using the mathematical model as a basis, the reliability requirements will be converted to the equivalent total failure rate (or MTBF) for each sub-assembly. The individual sub-assemblies and circuits for the mode are defined in the Product Identification Chart which defines the actual hardware used in each mode of operation and cross-references the reliability block in which each sub-assembly is used. Where a circuit or sub-assembly is used in more than one mode, this is presented in the Common Item Chart which results from the model derivations and product identifications.

The operating modes of the AN/BQQ-1 System as defined for this R/M effort in accordance with the Dependability Supplement are as follows:

a) Passive Detection

b) Passive Tracking

c) Passive Localization

d) Active Localization

e) Active Detection and Tracking

The apportioned Reliability numbers for the individual units and sub-assemblies, derived from the Reliability Block Diagrams and Product Identification Chart, will be given to Systems Engineering for inclusion in the System Unit Specifications as an additional design requirement. The R/M Department will supply consultation to the System Engineers for detailing and defining the reliability requirements and review the System Unit specifications to assure the inclusion of these requirements.

As design predictions are generated, the R/M Engineers will determine whether apportionments have been met by designers. Where apportionments are obviously incapable of being satisfied, trade-offs will be made with other sub-assemblies and new apportionments will be determined and distributed to the System Engineers for revision to the System Unit Specifications.

## f. PREDICTION

### 1. Reliability Prediction and Analyses

A mathematical prediction of reliability of the AN/BQQ - 1 Integrated Sonar System will be generated early in the concept phase and continously updated as circuits are developed. The initial prediction will be based on NAVSHIPS 93820 Method C, wherein an estimated number of parts of a particular type will be assigned an average failure rate per part and the total quantity of parts multiplied by their failure rates will become a first approximation of the equipment reliability.

As the circuit designs are generated, failure rates will be assigned to each part in the circuit based on its particular stress, and a Method D prediction will be derived. Stress analysis worksheets shown in Figure 1, 2, and 3 will be employed. Figure 1 will be the cover sheet for the stress analyses and will contain the necessary information to identify the circuit. Figure 2 will be back-up work sheets from the same circuit and will only require the drawing identification. Figure 3 will be a summary sheet with provision for grouping parts by type and providing other necessary information. Failure rates for the prediction will be obtained from NAVSHIPS 93820 for all parts except semi-conductors and tantalum capacitors, for which MIL - HDBK - 217 will be used.

Meanwhile a mathematical model will be generated to combine the individual sub-assembly failure rates into the different Reliability Blocks for each operating mode. (Paragraph 3 of this section indicates how mathematical models are generated.)

### 2. Maintainability Prediction and Analysis

A Maintainability prediction and analysis will be conducted early in the design phase. The procedure is detailed in Section C of this plan.

RAYTHEON

AN/BQQ-1 OPERATING STRESS ANALYSIS
(CONTRACT NObsr 93138)

Sheet ____ of __

Assembly Name ______________________ Date ______________

Assembly Designation ______________ Eng'r. ______________ Drawing No. ________

Assembly λ ______________ App'd. ______________ Rev. No. ____________

| REF. SYMBOL | PART DESCRIPTION | RATED STRESS LEVEL | OPERATING STRESS | OPER. STRESS / RATED STRESS | NON-STANDARD | F. R. ($\lambda x 10^6$) | REMARKS |
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4834-124 Rev 1 R/M

FIGURE 1 AN/BQQ-1 OPERATING STRESS ANALYSIS WORKSHEET COVER

RAYTHEON

AN/BQQ-1 OPERATING STRESS ANALYSIS
(CONTRACT NObsr 93138)

Sheet_____ of _____

DRAWING NUMBER______________________________ REVISION NUMBER_____________

| REF. SYMBOL | PART DESCRIPTION | RATED STRESS LEVEL | OPERATING STRESS | OPER. STRESS / RATED STRESS | NON-STANDARD | F.R. ($\lambda x10^6$) | REMARKS |
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R/M 4854-124A

FIGURE 2 AN/BQQ-1 OPERATING STRESS ANALYSIS WORKSHEET

RAYTHEON

AN/BQQ-1 OPERATING STRESS ANALYSIS
SUMMARY SHEET
(CONTRACT NObsr 93138)

Sheet_____of_____

Assembly Name________________________________ Drawing No.____________
Assembly Designation__________________________ Revision No.____________

| PART TYPE | QTY. | TOTAL $\lambda/10^6$ HRS. |
|---|---|---|
| Resistors | | |
| Capacitors | | |
| Transistors | | |
| Diodes | | |
| Transformers | | |
| | | |
| | | |
| | | |

TOTAL ASS'Y $\lambda$ ________________________/$10^6$ Hrs.

APPORTIONMENT________________________/$10^6$ Hrs.

REMARKS________________________________________________________

R/M Engineer________________

FIGURE 3 AN/BQQ-1 OPERATING STRESS ANALYSIS SUMMARY SHEET

3. Generation of Mathematical Models

a. Definition:

As defined in the Bureau of Ships Reliability and Maintainability Training Handbook, a system model is an analytical representation of the system in terms permitting assessment of the characteristic of interest.[1] For this program the characteristic of interest is the overall system reliability in each of its operating modes.

b. Procedures:

The procedure for generation of the system model will include the following steps:

1) Generation of a Reliability Block Diagram wherein each block represents one or more functionally dependent sub-assemblies, not necessarily located in the same unit.

2) Arrangements of the blocks in functional sequence, indicating those required for series, parallel or redundant paths.

3) Assignment or determination of reliability for each block.

4) Combination of the block reliabilities into a single mathematical model which will represent the probability of system ( or mode) successful operation.

c. Purpose:

The development of the mathematical model and the Reliability Block Diagram will make it possbile to evaluate system performance, prior to actual production of the system, with regard to the following characteristics:

1) Identification of critical parts/assemblies.
2) Results of trade-off studies.
3) Reliability apportionment.
4) Failure modes and effects.
5) Prediction analyses.

4. Incorporation of Failure Modes and Effects Analysis in Prediction

A Failure Mode and Effects Analysis will be included as part of the preliminary reliability prediction. Each block of the Reliability Block Diagram will be investigated for the effect of a shorted, open, or degraded output on the model performance characteristics. The concept employed will be to seek the answer to the question, "Given the fact that a block has failed in a particular manner, what is the probability of system failure?"

Where a catastrophic system failure would result, an intensive effort will be applied to provide some alternate method of performing the same function by the use of other equipment. The redundancy inherent in the system design will be utilized wherever possible to assure continuous operation.

5. *Use of Data for Prediction*

Failure rate data and prediction techniques will be in accordance with NAVSHIPS 93820 Method D except for the following:

1. Transistors other than stud-mounted. Use MIL-HDBK-217.
2. Diodes other than stud-mounted. Use MIL-HDBK-217.
3. Tantalum Capacitors. Use MIL-HDBK-217.

Where other NAVSHIPS 93820 Failure Rate data is used, appropriate notation will be made on the Reliability Stress Analysis Worksheets.

Other data sources such as Raytheon's own files, manufacturer's data, etc., will be used where no information is available from the preferred sources listed above. Additional supporting information may be supplied by test programs inititated for Critical Parts.

All data sources will be clearly indicated on every Reliability Prediction. Copies of each Reliability Prediction including stress analysis worksheets will be submitted to Bureau of Ships/Underwater Sound Laboratory according to schedule. The schedule will be updated as necessary to reflect redirection of effort or changes in scope. Additional copies of all reliability predictions and analyses will also be submitted to the Navy Design Review Audit Team's as required by contract

6. Periodic Review of Updating of Prediction

The Reliability Predictions will be updated every 90 days to reflect any changes in the design and configuration of the AN/BQQ - 1 System. Additional capabilities incorporated in the system and the changes incorporated as a result of R/M Department recommendations will be reflected in new failure rate apportionments and will require updating of predictions. Revised predictions and analyses will be submitted to Bureau of Ships and Underwater Sound Lab as they are generated.

7. Product Identification

In a continuing program of Reliability evaluation product identification is a primary requirement. At Raytheon SSD an established procedure will be followed for quick determination of the reliability status of the contracted equipment using product identification charts. The inital step in the procedure will be to define the System Reliability requirements and generate a block diagram as indicated in Section f-3. The previously determined reliability requirements, having been divided among the individual blocks, will be further sub-divided into the separate sub-assemblies and circuits which comprise these blocks. In conjunction with the configuration control, organization of the chart will be updated periodically to maintain an up to date listing, reflecting the latest changes in hardware. These hardware changes will be reflected into the overall Reliability Prediction and Mathematical Models.

## g. DESIGN REVIEW

### 1. Integrated Design Review

An integrated design review effort will be included in the Dependability Program to assure the adequacy of the equipment design. A series of formal design review meetings will be convened as detailed in Raytheon Policy and Procedures Manual, Procedure E10.004, included as Appendix A of this section. In addition to the specified participants, government representatives will be invited to attend. The Design Review Board will review all test results on completion of testing. Figure I indicates the design review information flow diagram that will apply to this program.

### 2. Independent Design Review

The R/M Department will conduct an independent review of the equipment design, in accordance with Procedure Number E8.014 of Raytheon Policy and Procedures Manual, included as Appendix B of this section. The elements of the review will include the following:

a) Part Stress Analysis
b) Circuit Design Adequacy
c) Statistical Circuit Analysis
d) Critical Parts Tests
e) Failure Mode and Effects Analysis
f) Part Specification Review

A detailed description of each of the above elements is contained in the following sections.

a) *Part Stress Analysis*

A detailed stress analysis of each part will be performed in order to determine whether parts are adequately derated.

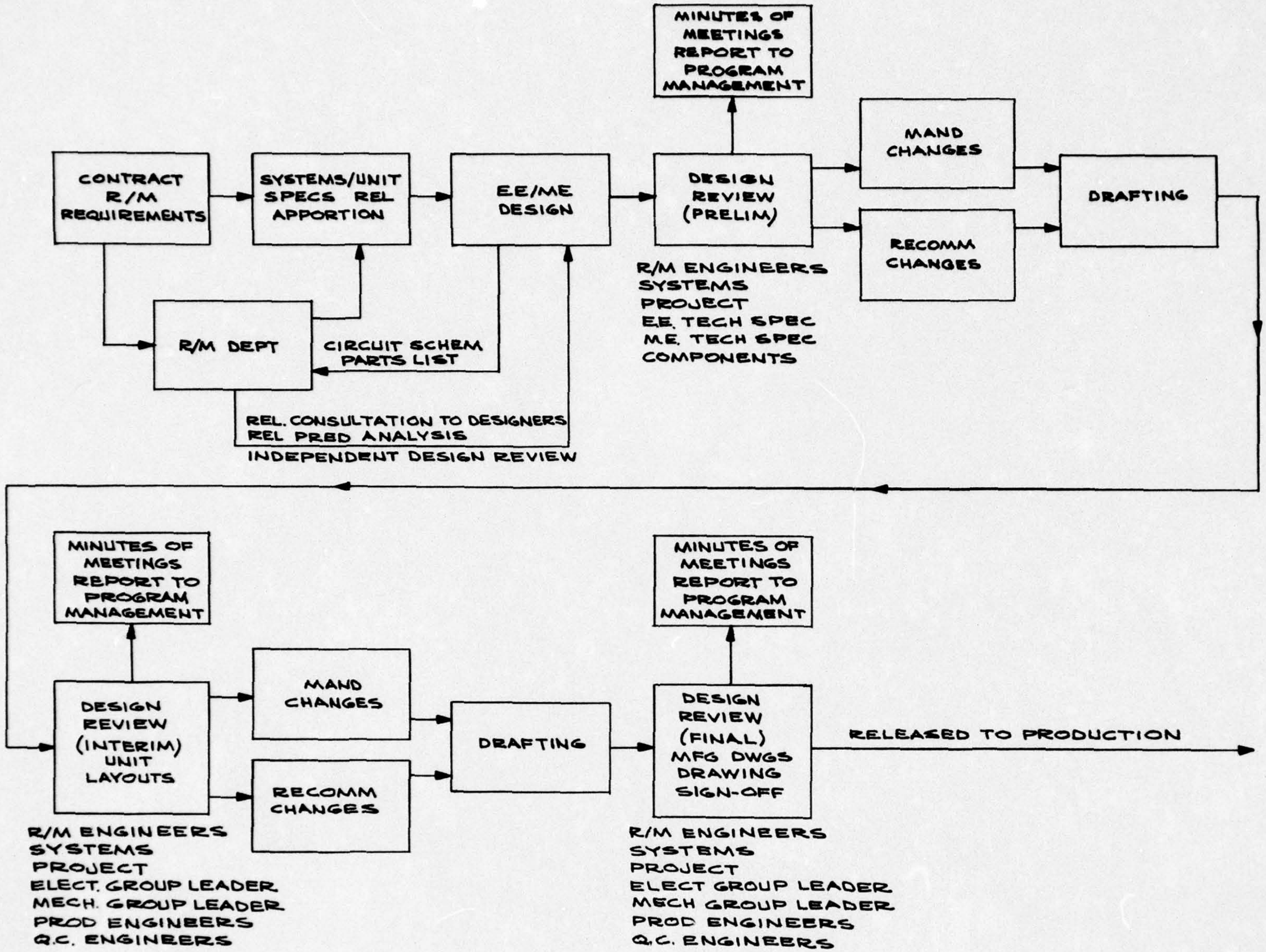


FIGURE 1 DESIGN REVIEW FLOW CHART

Adequate derating is defined as less than 25% stress ratio for all parts except tantalum capacitors, which will be less than 50% stress. Part derating values will appear in the R/M Design Manual which will be distributed to all Design Engineers.

b) Studies will be conducted by R/M Engineers, to evaluate circuits with respect to performance under adverse conditions of temperature stress, transients, etc. with regard to significant parameters such as gain, phase shift, and stability. Particular attention is given to those circuits deemed critical in function. A design review checklist will be employed as a minimum effort on these circuits. (ref. EXHIBIT 1). Purchase Specifications will be reviewed to determine part adequacy for the circuit application as well as standardization of part types and values. Where possible, parts will be selected from military standard lists such as MIL - STD - 242 E and MIL-STD - 701. Circuit simplicity and elimination of unnecessary parts will be a primary consideration for the circuit design review. Non-standard parts, where required, will be selected on the basis of established failure rates or known reliability potential and capabilities. The independent design review will include an investigation into the range and sensitivity of potentiometers and the possiblity of their deletion. Where a part failure may cause system malfunction due to secondary effects, provision will be made to minimize these effects. The required changes found by the R/M independent design reviews will be transmitted to the individual circuit designer for incorporation into the circuit. An internal R/M memorandum will record the recommendations for future reference at later reviews. The R/M Design Review team will be comprised of Electrical and Mechanical Design Engineers, Maintainability Engineers. Thermal Engineers, Statisticians and Failure Analysis specialists for this important effort.

c) Statistical Circuit Analysis

As a result of a computer programs investigation, and recognizing that the volume of output data will require significant analysis and evaluation time, Raytheon will apply the following supplementary program for critical circuit design evaluation.

1) The circuits will first be classified on the basis of their suitability for computer analysis, i. e., non-linear circuits which cannot be piecewise synthesized linearly will not be computer analyzed. Simlarly, items such as integrated circuits for which no complete or precise data can be obtained will not be computer evaluated. Every attempt, however, will be made to adapt as many circuits as possible for the computer program.

2) All critical circuits capable of computer analysis will be evaluated for:

(a) Worst Case

(b) Parameter Sensitivity

for DC and/or AC analysis, as required.

3) Those circuits in which costly or unique design components are involved will be analyzed for tolerance settings by a one-at-a-time Parameter Variation.

4) Those circuits which will specifically be high production circuits will be analyzed statistically to determine probable yields.

It is intended that the ECAP program which is running and debugged at Raytheon be used. However, the potential advantages in terms of time economy and less human error offered by NET -1 will not be ignored, and may be developed as a parallel technique.

Finally, since the volume of effort involved and the time required for output data analyses (frequency response curve drawing, stability diagrams, etc.) is very great, additional resources such as the ARINC analysis service will be considered as a subcontracting source.

d) Critical Parts

A critical parts program will be initiated. Results from testing of critical parts will be used as important inputs to the Design Reviews. The critical parts program is discussed in greater length in Section 2-h.

e) Failure Mode and Effects

In addition to the analysis of the system conducted during the Prediction phase, a continuing Failure Modes and Effects analysis effort will be applied during the Design and Development phase ( See Section D). The purpose of this effort will be to investigate the criticality of the subassemblies comprising the Reliability Blocks, and to assure that proper precautions aretaken against the most damaging failure modes. The results of the FM &E analysis will be provided as inputs to the Design Review effort.

f) Maintainability and Human Factors Analysis

The Electrical and Mechanical design will be examined for ease of maintenance as well as operability during the independent design review phase. Consideration of sufficient test points, fault isolation and location, self-test features and other trouble-shooting aids will be included in the maintainability input to the independent design review.

The Human Factors input will include consideration of location and ease of operation of controls, visibility and placement of operational indicators, readability of meter, and other design features which enhance the ease of operation of the equipment.

g) Parts Specification Review

Part specifications will be reviewed to determine that part requirements are detailed accurately and completely and testing requirements are adequate for assuring proper operation in the equipment. R/M Component Parts Specialist will review the specifications and indicate approval by sign-off. No parts specifications will be released for purchasing unless the indicated R/M approval is given.

h) Circuit Simplification

The R/M design review effort includes an investigation into the possible simplification of the circuitry, including elimination of all unnecessary potentiometers or adjustments that are not operator controls. Where a potentiometer is required in a circuit, the range and effect of the adjustment will be checked for compliance with the system specifications. Where unnecessary parts or overly complex circuitry is discovered, recommendations for simplified approaches will be presented as an input to the design review effort.

The results of the independent design review, noted above, will be documented in an internal memorandum to the R/M Project Engineer for incorporation into the Design Review Final Report.

As the results of the individual investigations become available, they will be presented personally to the responsible designer with a request for incorporation of the necessary changes. Where other constraints are imposed and the designer cannot comply, the decision for incorporation will be determined by the members of the formal Design Review Board.

## 3. Formal Design Review

### 3.1 Preliminary Design Reviews (Study Layout)

A preliminary review of each circuit will be conducted when the electrical concept has been determined, preliminary parts list have been completed and an initial layout is determined. The R/M Department will receive two copies of each preliminary schematic diagram and parts lists for review. One copy will be used for the circuit stress analysis and circuit review. The other copy will be reviewed by the Failure Mode and Effects Analysis and Statistical Analysis engineers. Parts lists will be required for the circuit analysis and the part specification investigations. Approximately one (1) week prior to the formal review meeting, the mechanical packaging concept drawings will be submitted to R/M for investigation by R/M Mechanical, Maintainability, Human Factors, and Thermal Analysis personnel. The results of all the above investigations will be combined into a single coordinated list of findings and recommendations to the Design Review Board. Where R/M recommendations are incorporated into the design by the cognizant designer prior to the formal Design Review Meeting, these recommendations will be deleted from the list. The advantages of personal discussion between R/M and Design engineers are many-fold. Primarily, the changes can be easily made with minimum of drafting effort, if present early in the design cycle. Secondly, many considerations can be revealed in discussions, which are not usually obvious from the circuit schematics or the Study Layout drawings. Raytheon has found the above procedure to be smooth working arrangement fostering mutual respect between R/M and Design Engineers on the working level.

3.2 Intermediate Design Review

This will be an interim review of unit designs allowing for incorporation of necessary changes to Design Layout drawings as a result of the electrical review. The purpose as defined in Raytheon Procedure No. E10.004 (Exhibit II) insure that the necessary changes are incorporated into unit designs as a result of the Study Layout Review.

3.3 Release Review

This will be a final review for sign-off and release of manufacturing drawings. At this point in time, the design is considered frozen and finalized. The purpose and procedure for the Release Review as defined in Raytheon Policy No. E 10.004, is a final review of all drawings and to freeze and design for a baseline configuration for Configuration Control..

3.4 Design Review Schedule

The design review meetings for each sub- assembly will be indicated as milestones of the AN/BQQ - 1 PERT schedules. All personnel contributing to these meetings can anticipate the scheduled reviews and will have sufficient advance notice to properly prepare their contributions. Where slippage occurs, the event will be re-scheduled on the updated PERT charts.

### 3.5 Navy Audit Team Submittal

A design data package will be submitted to the Navy Audit Team approximately one week after the Preliminary Design Review Meeting. The package will include the Schematics and Parts Lists and Study Layout drawings reviewed, with any changes incorporated which have been approved by the Design Review Board. The R/M Department will submit separately the circuit stress analyses conducted during the independent R/M Design Review effort.

## EXHIBIT I

### R/M DESIGN REVIEW CHECK LIST

1. Purchase Spec Part Compatibility with circuit requirements.
2. Use of non-standard parts where standard parts are available.
3. Simplification and/or deletion of parts.
4. Substitution of inherently high failure rate parts with lower failure rate.
5. Worst case part tolerance.
6. Variability of part parameter through environment.
7. Application and sensitivity range of potentiometers. Deletion of potentiometers if possible.
8. Secondary effects of part failure.
9. Special transient considerations.
10. Input variations possible -- tolerance analysis.
11. Cost reduction at no degradation of reliability.
12. Circuit stability.
13. Reliability of relays - Diode Suppression.
14. Agreement of major circuit performance parameters with unit specification requirements.

## DESIGN REVIEWS

*1. PURPOSE

This policy is established because of increasing demand by military and commercial customers for products which perform satisfactorily, operate reliably in their specified environments and are readily maintainable in the field. The current trends and requirements, particularly of government agencies, in specifications, schedules and types of contracts dictate increased emphasis on the reliability and maintainability of designs. Formal design reviews, at specific intervals in design and development programs are intended to fulfill these requirements. Design reviews of changes in articles released for production are also established to assure full consideration of all relevant factors.

*2. POLICY

2.1 Formal Design reviews shall be implemented on:

2.1.1 All systems and design efforts including proposal efforts, when it may reasonably be assumed that the end product will achieve production status.

2.1.2 Design efforts on changes affecting articles either released for/or in production.

2.1.3 Systems and design efforts on selected single items or system programs which involve substantial commitments of government and/or company funds.

2.1.4 All system and design efforts where there is a company or customer reliability, maintainability or similar type requirement.

2.2 This policy applies to military sponsored programs.

2.3 Formal reviews of Raytheon designs, Subcontractor designs to Raytheon specifications and design or specification changes will be conducted on all projects per paragraph 2.1 unless specifically waived. Function Managers shall be notified in writing of intent to waive. Authority to waive is delegated as follows:

2.3.1 Projects covered by paragraphs 2.1.1, 2.1.2, and 2.1.3:

a) Program/Project value - over $100,000 - Division General Manager

b) Program/Project value - under $100,000 - Cognizant Program Manage

2.3.2 Projects covered by paragraph 2.1.4 may only be waived by the Division General Manager.

2.4 Function Managers may request consideration of waivers when such action is believed warrented.

2.5 System/Design reviews shall be made a part of PMA Funding. Therefore, effort required for these reviews must be estimated and bid by functional areas which may normally anticipate participation in such reviews.

2.6 Additional reviews may be requested by Function Managers and Design Review team members when believed warranted. Additional design reviews shall be conducted at the discretion of the Cognizant Program Manager.

*3. DEFINITIONS

3.1 Formal Design Reviews will consist of:

3.1.1 Preproposal Review: An appraisal, on a product basis, of the suitability of the proposed overall System/Design approach for meeting the specified requirements in light of competitive strategy, design feasibility, reliability and maintainability, up-to-date techniques, productibility, cost and delivery schedule.

3.1.2 Concept Review: An appraisal, on a product basis, of the overall approach to a functional product or system in light of contractual requirements, made at the earliest practicable time after issuance of systems and unit specifications.

3.1.3 Electrical Review: A preliminary review, on a unit or sub-unit basis as applicable, of the electrical schematics and parts list, mechanical study layouts and applicable packaging requirements. The review is intended primarily to insure incorporation of reliability and maintainability factors and other contractual requirements in the basic design. Normally, this review will be held at a time when preliminary schematics and parts lists have been prepared, and after preliminary study layouts have been completed by mechanical design. This should insure that the electrical and the mechanical design of unit or sub-unit has not progressed to a point where changes would be both costly and time consuming.

3.1.4 Design Layout Review: An interim review of unit designs. This review should be held as soon after necessary changes required, as a result of electrical review, have been incorporated and design layouts for units are completed. This review is intended to insure that maintainability, productibility, value engineering and environmental use factors have been incorporated into the design. It is intended that this review shall be completed before detail drawings have been started to insure that necessary changes may be incorporated before drafting has progressed to a point where changes become excessively costly and time consuming.

3.1.5 Release Review: A final review involving manufacturing drawings. This review is intended to insure that manufacturing drawings are adequate, accurate, and complete. This review should be held as soon as possible after the necessary changes required by the design layout review have been incorporated and the detail manufacturing drawings are complete. At this time the drawings (layout, detail, etc.) shall be given the necessary sign-off approvals (Engineering, Manufacturing, Product Assurance).

3.1.6 Design Change Review: A review of major design changes occurring after release to production. This review, when required, must be conducted prior to the issuance of an ECO.

3.2 Manufacturing Design Review Representative:

An individual appointed by the Manufacturing Manager, having overall responsibility both for Manufacturing participation in design reviews and to assure that the design, at the time of release, is ready for production.

3.3 Design Review Team:

Normally, the Design Review Team consists of the Systems, Design, and Reliability/Maintainability Engineer(s), the responsible Manufacturing Design Review Representative, and the Design Review Chairman. Other specialists may be added as required. The Design Review Chairmanship is normally delegated by the appropriate Program Manager to the appropriate Engineering Projects or Proposal Manager. All other participants are assigned by their Function Manager at the request of the Design Review Chairman.

3.4 Check - Lists:

For the guidance, as applicable, of the Design Review Team members. Check Lists provided for this purpose are:

3.4.1 Systems Check List, Exhibit II

3.4.2 Check List for Electrical Design and Component Parts, Exhibit III

3.4.3 Check List for Mechanical Design Specialist, Exhibit IV

3.4.4 Value Engineering Check List, Exhibit V

*3.4.5 Reliability Check List, Exhibit VI

*3.4.6 Maintainability Check List, Exhibit VII

*4 RESPONSIBILITIES

4.1 Program Managers, or their delegated Design Review Chairman, will be responsible for conducting Design Reviews in accordance with this Policy and the attached procedure, (Exhibit I), as well as coordinating, resolving differences, and reporting on all recommendations submitted. The Review Team recommendations will be placed in either of two categories: mandatory or desirable. Mandatory recommendations must be carried out by the designer; desirable recommendations are at the descretion of the responsible design group leader. Where desirable recommendations made by the design review team are rejected, the cognizant design group leader must furnish in writing to the Design Review Chairman his reasons for rejection, so that they can be incorporated in the design review report. Mandatory changes shall include those which are necessary to meet unit specifications, military specifications, or special reliability and maintainability requirements. The Review Chairman is further responsible for scheduling reviews, notifying participants of time and place as well as review meeting topics to be considered and insuring the provision of necessary review material (drawings, specifications, etc.) to the participants at a reasonable (at least two (2) days) time prior to the review meeting.

4.2 Function Managers will provide for participation in Design Reviews by designating qualified personnel and providing sufficient work time for performance.

4.3 Representatives will prepare for Review meetings through study of design drawing, specifications, et cetera, and participate with the intent of recommending constructive design improvements.

4.4 The design of the product and its conformance to specifications is the responsibility of the design engineering group, and the actions, findings, and recommendations of the Design Review Team do not, in any way, relieve the design engineering group of its assigned responsibilities.

h. PARTS AND MATERIALS CONTROL. (MIL-E-16400)

1.0 Purchase Order Review and Sign-Off

Purchase orders for parts and/or materials required for the AN/BQQ-1 ( ) Program will reference the applicable paragraphs of relevant specifications, define any parameters of specific interest, note special requirements and will preferably require Government source inspection.

2.0 Specification Sheets Review and Sign-Off

Parts and/or materials required for the AN/BQQ-1 ( ) Program shall comply with the Raytheon Specification Sheet and/or Applicable MIL Specifications. Where no approved specifications exist, a Raytheon Specification Sheet shall be generated for that item. Each Raytheon Specification Sheet relevant to the AN/BQQ- 1 ( ) Program shall be reviewed and approved by the R/M Department. The Purchase or Manufacturing Order for any item shall contain reference to the Raytheon Specification or MIL Specification for that part, together with any specific requirement.

3.0 Critical Parts Testing

Parts deemed critical to the functional operation of the AN/BQQ-1 ( ) System, shall be subjected to a test program specified by the R/M Department. The program shall be designed to assure functional capability within the required environmental limits. Testing may include tests to failure, accelerated life tests, special environmental tests or infrared tests (See Paragraph 4.0).

4.0 Infrared (IR) Testing

Supplementary test program will be incorporated in the AN/BQQ-1 R/M analysis effort, using infrared scanning techniques, of active circuits to provide information as to their performance. Basically the program will be divided into three discrete parts; first, a plan for inspection for design purposes of the IR topography of selected circuit boards in the system, secondly, a testing program for monitoring the radiance variation on a representative sample of approximately twelve circuits considered critical from a reliability standpoint, and thirdly, a program of testing for adequate internal thermal conductivity for semiconductor components. Infrared testing will provide capability for assessing the junction to case conductivity or semiconductors.

5.0 Vendor Monitoring and Approval

Parts and material vendors for the AN/BQQ-1 ( ) Program will be monitored in accordance with the Quality Assurance practices referenced in Section k, Paragraph 2.1 and 2.2. Vendors selected to supply parts and materials for use on the AN/BQQ-1 ( ) Program will be fully approved in compliance with provisions of the Raytheon Quality Assurance Manual and MIL-Q-9858A.

The Product Assurance Project Manager will be consulted in selecting vendors for critical parts. He will provide R/M participation in reviews of vendor Quality and Reliability capability and will assist in evaluation of vendor ability to meet the requirements of the Dependability Program. He will also monitor recommendations for upgrading vendor product reliability, specifying special tests to be performed on critical parts, and arrange for providing vendors with reliability data generated by Raytheon on critical parts.

Alternate source parts and materials vendors shall demonstrate capability to meet this Dependability Program in the same manner as other vendors.

## 6.0 Quality Control (Incoming Inspection)

Parts and materials supplied in conformity with the foregoing provisions shall be subject to Incoming Inspection practices in accordance with Raytheon Policy and Procedures Manual. (See Figure 1).

Incoming material will be inspected in accordance with Raytheon Quality Assurance Manual. Sampling, will be in accordance with MIL-105D. AQL shall be adjusted for critical characteristics. Specifications and procedures for tests of special and critical parts will be generated by R/M Department. Incoming Inspection shall notify R/M Department on receipt of material that calls for testing in the procurement documents.

The Product Assurance Project Manager shall insure that results of this testing and data generated are properly recorded and sent to vendor if necessary.

Rejected material shall be processed through the Materials Review Board in accordance with the Quality Assurance Manual.

On every rejected characteristic, the vendor will be required to satisfy Quality Assurance that adequate measures have been implemented to assure non-recurrence.

Pending the demonstration of the effectiveness of measures taken by the vendor to correct the causes of such rejections, this item shall be processed to a tightened AQL.

The Product Assurance Project Manager will act to ensure close liaison between Incoming Inspection, Vendor Quality Control Engineering, R/M Department

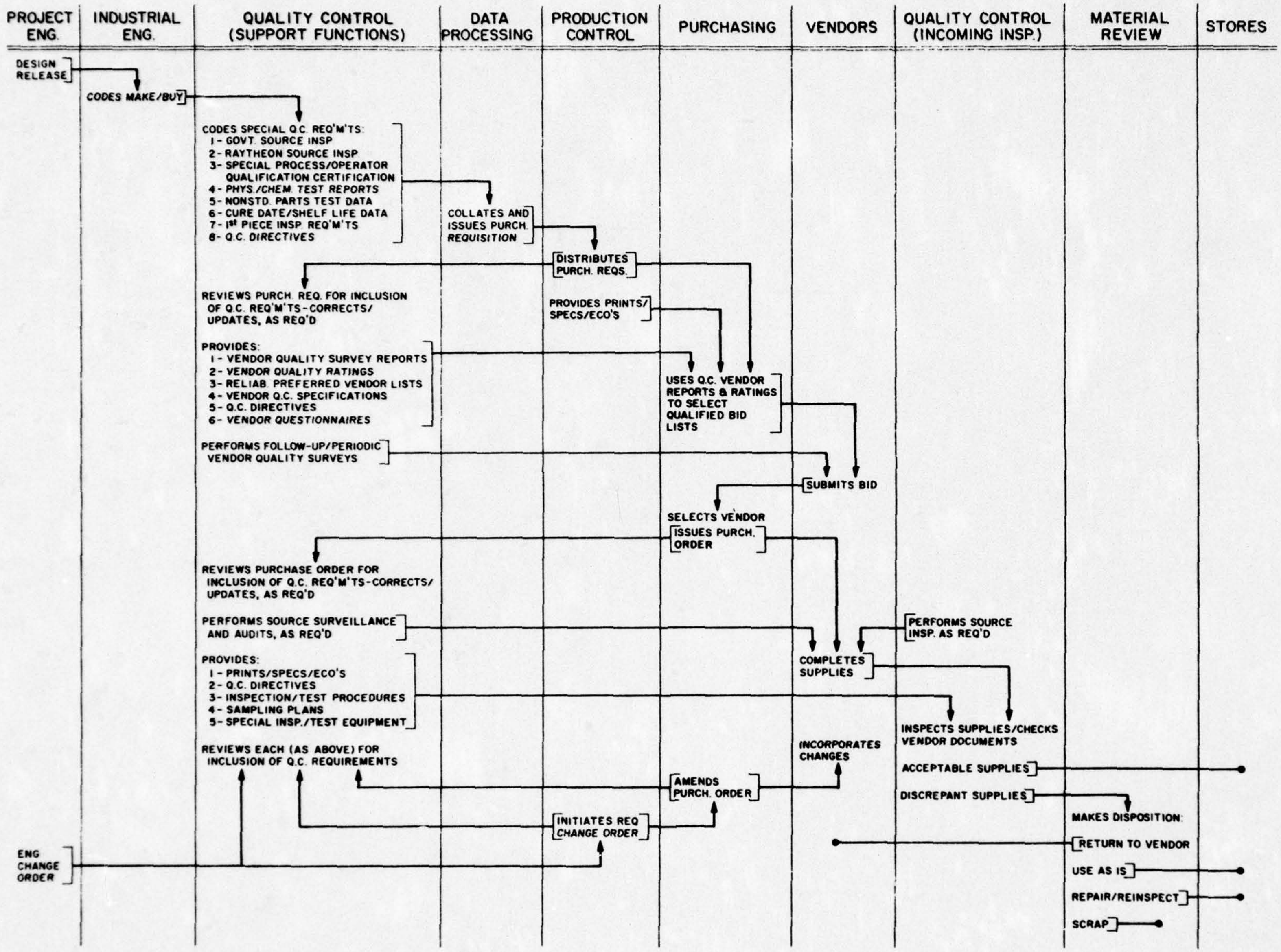


FIGURE 1 QUALITY PROGRAM FOR CONTROL OF PURCHASES

and Design to insure that project goals are adequately supported.

## 7.0 Production Handling Procedures

The storage and handling of all AN/BQQ-1 parts and materials will be in accordance with Raytheon Policy and Procedures for all controls necessary to identify this material and prevent degradation in storage.

The Manufacturing Practices Review, referenced in Section K, Paragraph 1, shall be particularly applicable to the production handling of parts and materials. Such Manufacturing Practices shall delineate the directions, controls and evaluation necessary to assure the maintenance of good workmanship procedures.

Items rejected as unsatisfactory by visual and mechanical inspections and tests throughout the production phase shall be tagged and processed in accordance with the Failure Reporting and Analysis directives referenced in Section M.

The Product Assurance Project Manager will review a summary of all Inspection including both quality trends and cumulative totals of inspection rejections to be submitted to him on a weekly basis by Quality Assurance.

## 8.0 Non-Standard Parts

Non-standard (special and critical) parts listings will be reviewed and continually updated to minimize the variety and number of such items. Where non-standard and parts approval requests are necessary the requests will be reviewed by the Product Assurance Project Manager for compliance with MIL-STD-749. Non-standard part waiver approval requests will be reviewed by the R/M Components Engineers for validity prior to submittal for customer consideration. Such reviews will take into account any previous part history, test data and reliability stress analyses which could provide Dependability background. The Raytheon Specification Sheet for any non-standard item will be reviewed and approved as delineated in Paragraph 2 above.

9.0 Preferred Parts

Standard preferred parts listings will be generated and maintained for new designs. These listings will be subject to review by the Product Assurance Project Manager. The review will take into consideration the associated Raytheon Specification Sheets or applicable MIL Specification for compliance with MIL-STD-242E relative to the application.

10.0 Sub-Assembly Testing

The parts and materials control loop will be closed by the monitoring of all sub-assembly, module and unit production testing. The resulting test data will be analyzed to assure the completeness of the test program in determining the item capability. Malfunctions arising during such tests will be reviewed to determine part of material contribution. Part or material failures will be processed as indicated in Paragraph 6 above. Corrective actions, as necessary, will be generated and submitted to the Product Assurance Project Manager for approval. On approval, such corrective action will be implemented and the results monitored to assure the validity of the follow-up action.

11.0 Use of Failure Data Sources

A continuous review program of failure data sources will be maintained. Consideration will be given to such relevant sources as previous "in-house" test reports, previous and current field failure report and analyses, applicable

IDEP component part tests report and other vendor or technical literature for additional part data.

The information derived from this review will be applied to part selection, reliability and maintainability apportionments and predictions, and as background data for design reviews.

## i. CONFIGURATION CONTROL

1. Under the Raytheon Submarine Signal Division Configuration Control System, Engineering drawings are released for distribution with specific effectivity and with proper Engineering approvals. Master record cards are maintained to indicate the latest drawing change letter applicable and other Engineering, Purchasing or Administrative Departments.

The Engineering L/M release constitutes an equipment configuration "base-line" to which all subsequent engineering design changes are applied. Upon receipt of the Engineering L/M release, Q. C. configuration control personnel develop: (1) a Master Configuration Log in numerical sequence for each Contract End Item ( C. E. I. ), and (2) a Master Configuration Log in numerical sequence for the equipment system. The first master log is applicable to the final shipment of all C. E. I. 's, while the second master list is used as a working document by Q. C. Inspection and Test. From the master configuration log, Assembly Control Documentation Requirments forms are filled out for each assembly and issued to the Inspection and Test department stations.

As the fabrication cycle commences, Q. C. configuration status cards are attached to various assemblies. These status cards cards denote the assembly number, drawing revision, and the L/M revision to which the a ssembly was made. Once the assembly is delivered to the inspection station the inspector checks the master configuration log to determine whether or not there have been any additional design changes. He then inspects the assembly to the lastest revision and verifies ( by stamping the configuration status card) that the assembly was actually made to the latest design configuration. The Assembly Control Documentation Requirments information, previously supplied and continously updated, is used as an aid in performing these inspection functions.

As lower level assemblies are combined to form a Contract End Item, a configuration status card for the C. E. I. is attached, noting the assembly number, drawing revision, and L/M revision. A further check is then made of the revision to which all the lower level assemblies were made. These lower level assembly configurations status cards are forwarded to the configuration control center where the information is posted to a master C. E. I. configuration record. At this time, the revision to which the lower level assemblies were made is verified (by stamping the appropriate drawing revision) in the master configuration record. Serial numbers are recorded, test and inspection reports are reviewed for completeness and attached, and the C. E. I. is prepared for shipment. As a final configuration verification prior to shipment all configuration records are checked against the master configuration log and become a part of Q. C. 's permanent records. These revision changes are introduced into the Q. C. configuration control system at the Master Configuration Log Level. These changes are recorded at this level and are then issued to the inspection stations as revisions. This sequence is done immediatley upon receipt of the design change notice, thus minimizing costly rework due to improper equipment configuration level. The ECO Processing cycle, the configuration control flow, and the configuration control records are shown in Figures 1, and 3, respectively.

2. The Dependability Organization is phased into the program by notification of all changes in status of the equipment configuration through daily change reports from Engineering, and overall system summary reports from Configuration Control. The changes will be evaluated for impact on maintainability and reliability and predictions and models will be updated to reflect new configurations on a monthly basis.

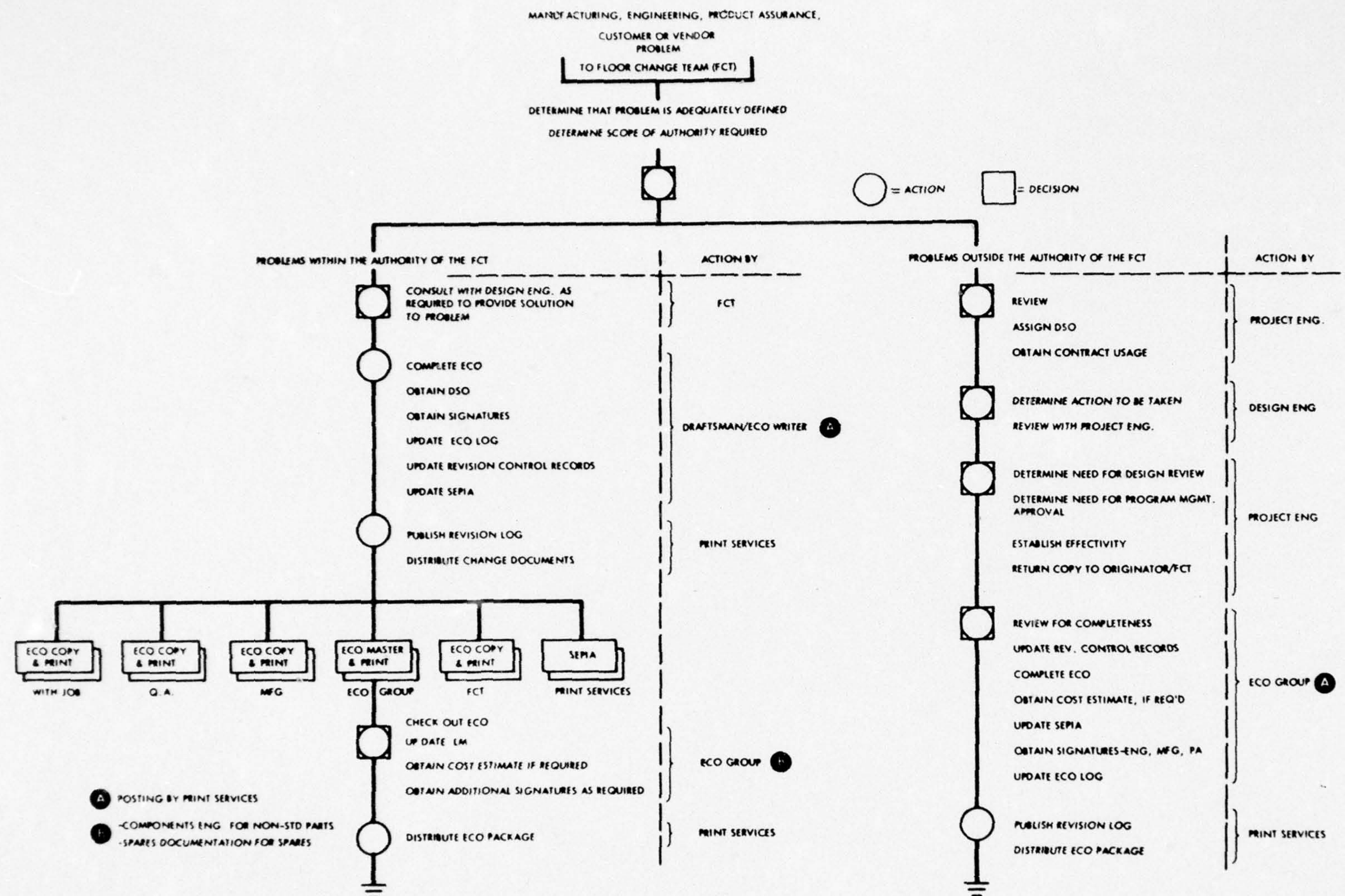


FIGURE 1 ECO PROCESSING CYCLE

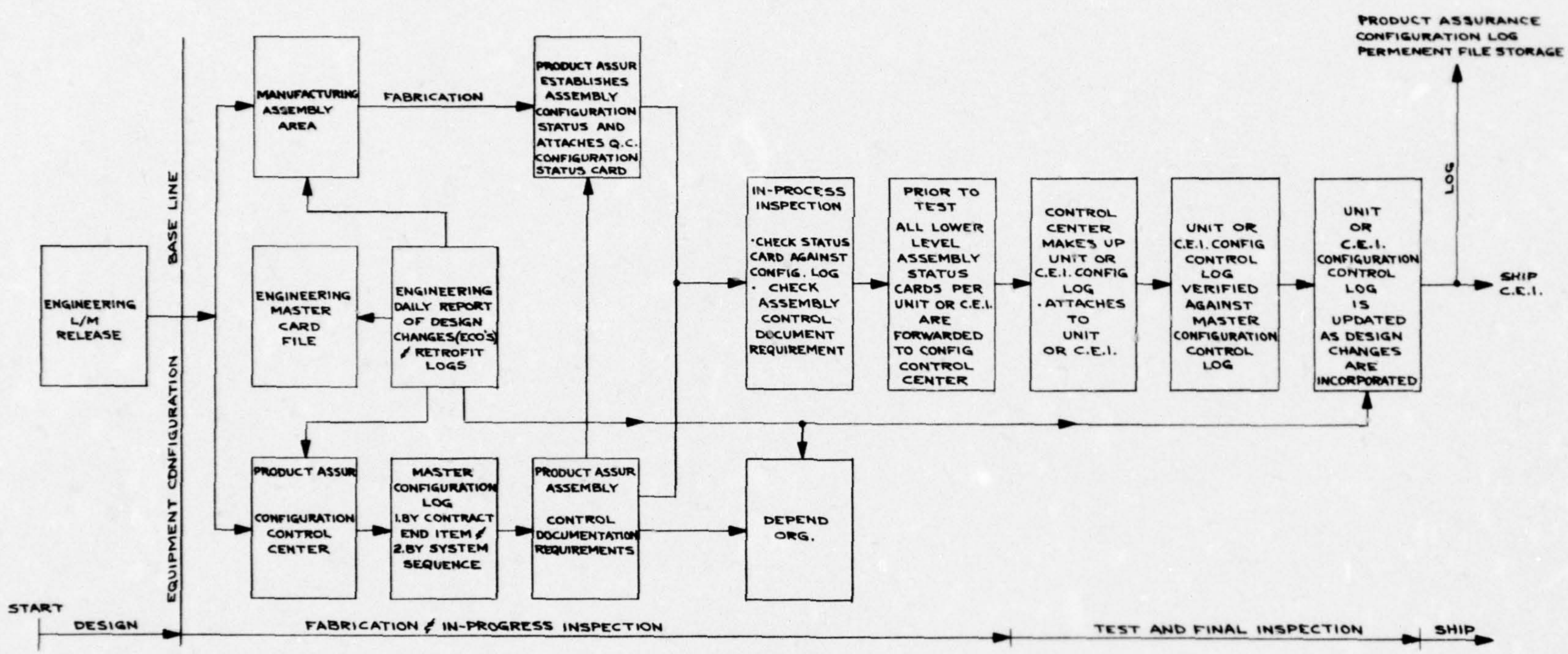


FIGURE 2 CONFIGURATION CONTROL FLOW

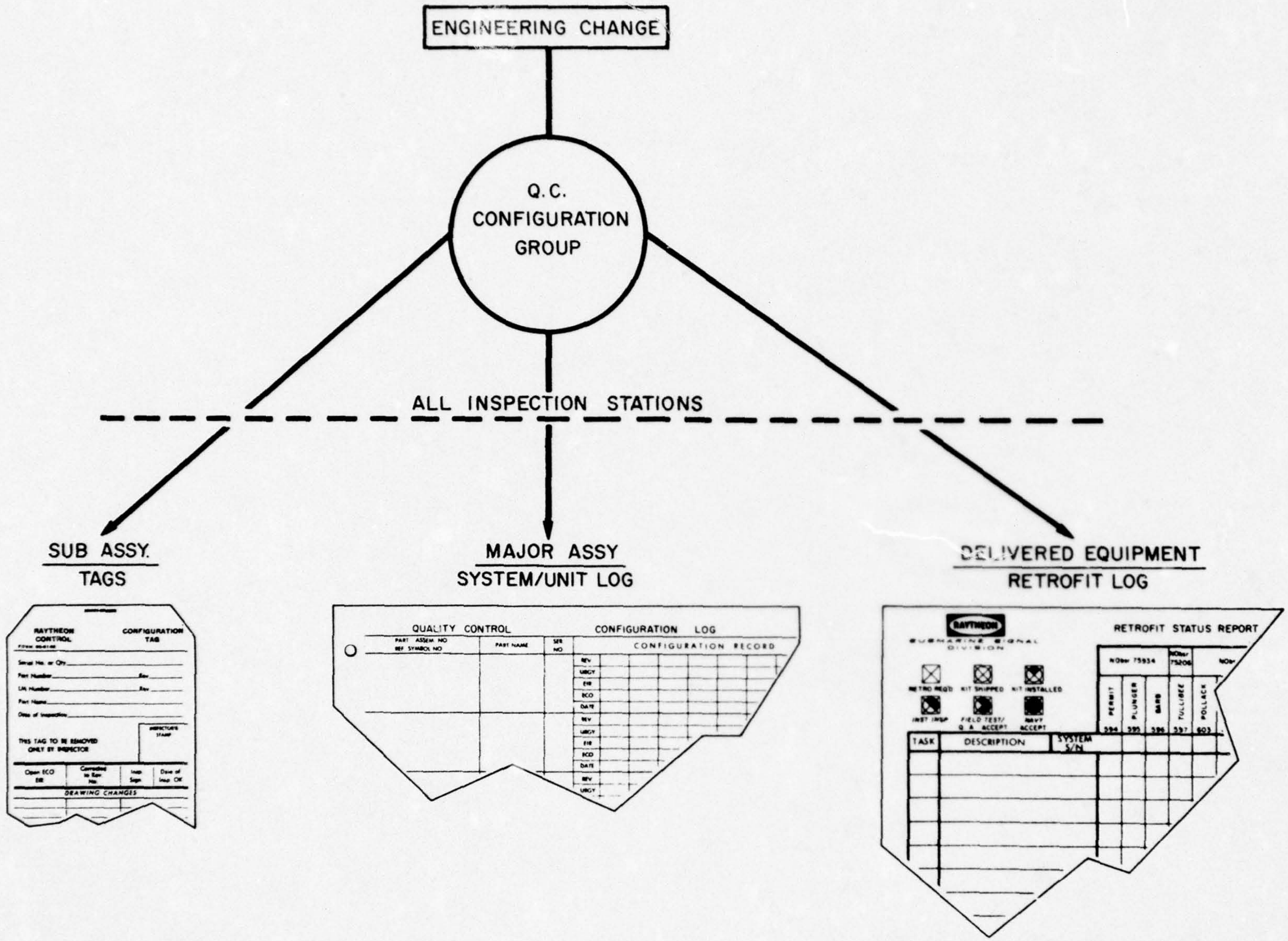


FIGURE 3 CONFIGURATION CONTROL RECORDS

## j. SUB-CONTRACTOR AND VENDOR CONTROL

### 1. Application of Dependability Program to Sub-Contractors and Vendors

A sub-contractor and vendor surveillance program will be implemented to assure adequate supplier Dependability procedures and techniques, compatible with Raytheon practices. In conjunction with vendor monitoring and approval policies, (Section h, Paragraph 5) suppliers of subcontractors and major non-standard parts and materials procured for the AN/BQQ-1 Program will be required to show compliance with specified reliability requirements. Subcontractors will be notified of the Reliability apportionments and will be continually monitored as to their achievement of these goals. Surveillance of suppliers processes and test methods will be conducted by the Quality Assurance Department Vendor Surveillance teams. A report will be generated for each supplier surveyed and a constant check will be maintained at incoming inspection to determine continued quality of product. Where large improvements in reliability are obtained, the manufacturer's apportioned reliability goal will be up-dated and trade-offs made. The Sub-contractors will be required to submit periodic R &M status reports.

### 2. Monitoring of Supplier R & M Programs

The subcontractors "in-house" R & M procedures will be reviewed for adequacy. Where the extent of the sub-contract requires " on-site" monitoring, a resident Raytheon representative will coordinate supplier and Raytheon R & M programs. The resident Raytheon representative will monitor sub-contractor fabrication procedures and testing. Periodic up-dating and feed-back of data will provide a continuous measure of progress toward the apportioned goals.

3. Vendor Dependability Programs (Critical Parts)

Critical Parts, as determined by Sections D & F will require closer scrutiny by Raytheon. The suppliers of critical parts will be required to submit test data along with delivered parts. The test data will be incorporated in the Raytheon Predictions and Apportionments as modifications of the basic part failure rates. Periodic audits will be held at the vendors facilities to review processes and discuss problem areas.

4. Specification Control on Non-Critical Components

Suppliers' purchasing specifications will be reviewed as required to assure the use of MIL parts and materials in accordance with MIL-E-16400. Where sub-assemblies are supplied a review of vendor stress analyses will assure adequate derating of parts.

5. Qualification Testing ( If Required)

Vendor qualification test programs will be reviewed and approved by Raytheon prior to the start of testing. Evaluation of sample sizes for statistical significance as well as stresses applied and accept/reject criteria will determine Raytheon confidence in test results. Test data will be supplied and reviewed prior to lot acceptance.

6. Vendor Facilities Inspection

In conjunction with Raytheon Quality Assurance Vendor Survey Teams, R & M representatives will evaluate vendor capability and review vendor R & M programs. The Vendor Survey Team will define minimum acceptable facilities and submit reports of all vendor investigations. The results of these surveys will be maintained on file and up-dates as required by program changes.

## k. MANUFACTURING CONTROL

### INTRODUCTION

In order to assure meeting of Dependability goals for the '65 Buy of AN/BQQ-1 integrated sonar systems, the Quality Control Department will play a vital role.

Besides implementing the relevant portions of the Q. C.Program Plan for the '65 Buy, in which appraisal of quality and feedback of quality data to cognizant areas are both covered in detail, all of the Q. C. effort will be reviewed for adequacy of coverage.

This review will cover the phases of Q. C. activity listed below, as well as any others which may be already in existence or developed during the subject contract:

1. Adequacy of the Quality Assurance Manual, both as to its relationship with MIL-Q-9858A and its comprehensiveness as a support function to Reliability/Maintainability.
2. Adequacy of the Workmanship and Standards Manual as delineating practices that minimize degradation of Reliability and/or Maintainability and assure compliance with applicable portions of MIL-E-16400.
3. Adequacy of all inspection procedures in appraising factors which will contribute to or degrade the Reliability/Maintainability of the equipment.
4. All Inspector/Tester reports will be reviewed for awareness of and applicability to the Dependability concept.

5. Configuration control and configuration status will be reviewed for adequacy. All configuration information issued by Q. C. will include the Dependability function in the distribution.

6. Statistical analyses of Q. C. data will be jointly reviewed and the types of analysis will be appraised for adequacy of coverage in the dependability area.

7. Quality Planning will be reviewed for dependability adequacy; and all jointly agreed on supplements incorporated to maximize equipment dependability and/or effective dependability management.

8. At the action level of the Q. C. effort, the interfaces between Q. C. and Reliability/Maintainability can best be illustrated with a flow chart. Figure K-1 illustrates the constant interchange of information that takes place throughout the design, fabrication and shipment of AN/BQQ-1 equipment between the two functions.

1. <u>MANUFACTURING PRACTICES REVIEW</u>

All standard and any special Manufacturing Practice Procedures generated in support of this project will be reviewed. The review shall be performed during the closing stages of the equipment design and development phase. A panel comprising representatives of Industrial Engineering, Systems Engineering, Quality Assurance and R/M shall verify the completeness and determine the applicability of these procedures to the Manufacturing

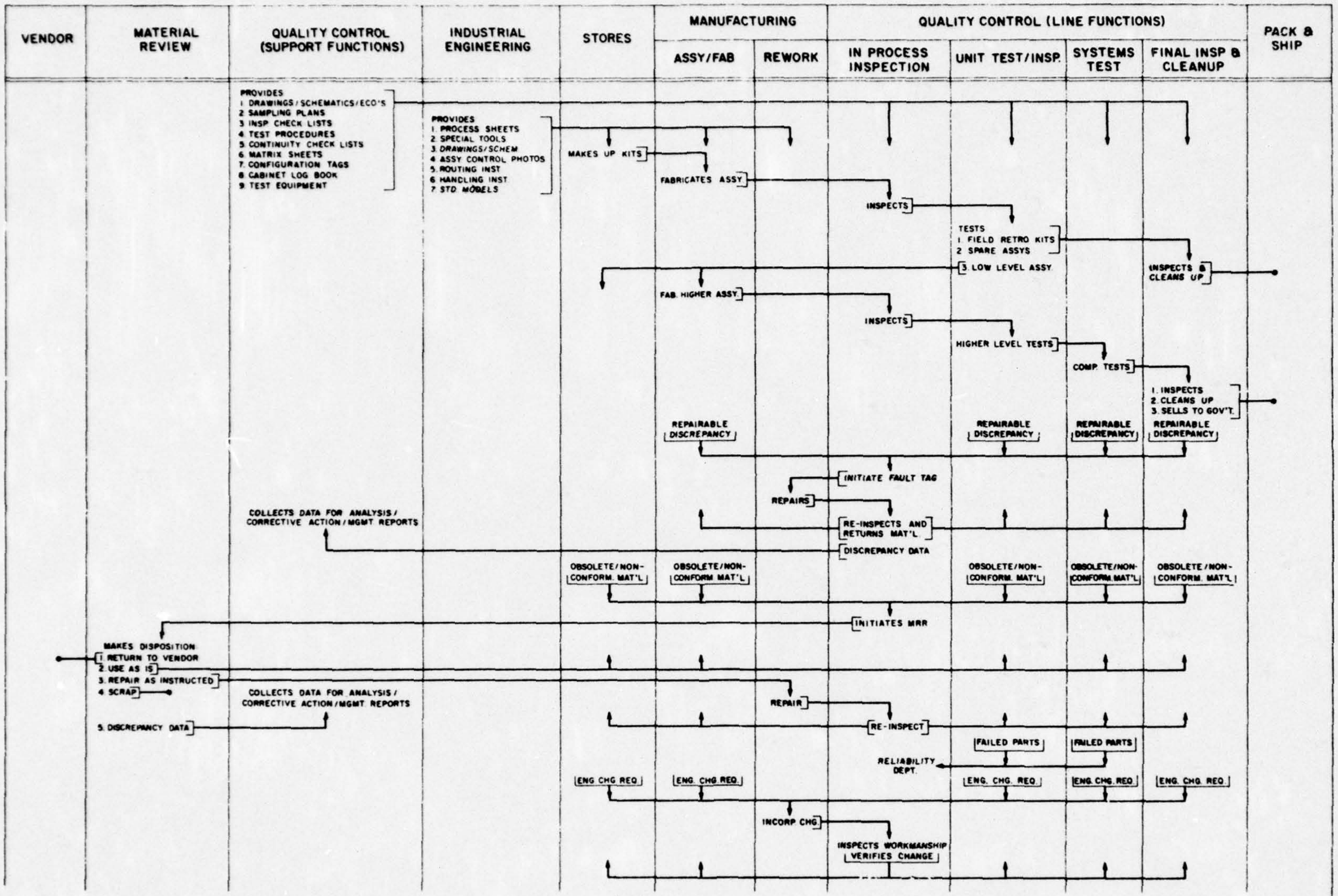


FIGURE 1 QUALITY PROGRAM FOR CONTROL OF MANUFACTURE

Product Program. The procedures shall be reviewed periodically, at intervals determined by the initial Review Panel, to assure continued validity and applicability to this project.

Any new Manufacturing Practice Procedures and/or amendments to existing procedures, submitted subsequent to the initial review shall be approved prior to incorporation into the Integrated Sonar System AN/BQQ-1 ( ) Standard Manufacturing Practices Manual.

## 2. PRODUCTION MONITORING

The following areas of Production Activity shall be monitored:

### 2.1 VENDOR SELECTION

It shall be determined that selection of sub-contractors and vendors is on the basis of capability to meet with Dependability Program requirements. Procurement documents shall be reviewed to assure the inclusion of adequate vendor task definition in the areas of equipment or part function, performance, reliability and maintainability. The Vendor Quality Control shall be responsible for providing the minimum acceptability standards to be imposed on suppliers.

### 2.2 VENDOR SURVEILLANCE

The vendor shall be required to submit an acceptable Dependability Program Plan. The Vendor's Dependability Plan shall be approved by the Product Assurance Project Manager. Any amendments to the vendor plan as submitted, which are required by the Product Assurance Project Manager, shall be implemented.

## 2.3 PROCESS DEVIATIONS

The Quality Assurance representative at any facility engaged in manufacturing against the AN/BQQ-1 ( ) project shall bring to the notice of the Product Assurance Project Manager any deviation from the Raytheon Manufacturing Practices as approved in Paragraph 1 of this section.

## 2.4 MANUFACTURING SURVEILLANCE

It shall be the responsibility of the Quality Assurance representative to advise the Product Assurance Project Manager of the status of "incoming" and "on-line" inspection problems.

The Product Assurance Project Manager shall be included on the distribution of all manufacturing inspection summaries and test reports.

## 2.5 WORKMANSHIP

The implementation of measures designed to maintain an index of equipment dependability is contingent on the standard of workmanship applied during manufacture. To complement the existing procedures, Personnel in conjunction with the Quality Control Department will conduct a manufacturing indoctrination and dependability training program. The training program will emphasize the responsibilities of the individual in the manufacturing of equipment.

## 3. RELIABILITY SAMPLING AND TESTING

In conjunction with Quality Assurance and Manufacturing Control schedules, a program of reliability testing during equipment manufacture will be implemented. Randomly selected samples from each level of equipment configuration will be subjected to tests designed to validate reliability predictions and evaluate performance.

Manufacturing techniques which are determined to be contributory factors to any failures occurring during these tests shall be immediately corrected.

## 1. COST EFFECTIVENESS

Considerations of cost-effectiveness with regard to maintainability or reliability trade offs, will be investigated. These will include use of throw-away modules, replacement at lowest repairable level and replace versus repair concepts.

The Dependability Organization will evaluate and approve all cost reduction suggestions for impact on system dependability. The primary purpose of this review will be to screen out those cost-reduction ideas which will significantly degrade the system dependability. Areas of investigation will include standardization of parts, changes which enhance interchangeability, less costly fabrication techniques, easier assembly procedures, and elimination of costly processes.

Value Engineering concepts will be applied to those areas where redesign cost reduction will provide equivalent performance without degradation of dependability.

## m. FAILURE ANALYSIS AND CORRECTIVE ACTION

### General

Just as design review is one of the most important areas of reliability assurance during a development program, a comprehensive failure analysis and corrective action program is of equal importance during equipment production. Raytheon Submarine Signal Division has extensive experience in the conduct of such programs, and standard policies and procedures have been developed for recording and processing in-plant failure data. Field failure data reported on BuShips Form 10550-1 can also be processed, and field failure analyses are currently being performed under Contract Nobsr 91276. However, since this program plan is concerned primarily with an in-plant failure analysis program for AN/BQQ-1 fiscal '65 Buy systems, only the in-plant procedures are detailed here. Figure 1 is a flow chart outlining these procedures.

### In-Plant Failure Analysis

Failures experienced during system test, unit test, module test, or other special in-plant test (such as environmental tests of subassemblies) are reported on Reliability Data Reports (Figure 2). These are three-part, tag-type forms consisting of bristol top and bottom cards and a tissue center sheet. When a failure occurs, the tissue center sheet is forwarded to Production Control, which issues a replacement part to the test area. The failed part, with the bristol RDR tags attached, is sent to the Components Analysis Laboratory, where the failure is verified and the part analyzed for failure mode and mechanism. When the part analysis is completed, the part is forwarded with the RDR tag to the Material Review Board (MRB) area for disposition, and the original RDR card, which now contains the coded laboratory failure mode analysis, is sent to the Data Processing Group for keypunching. In addition, a detailed In-Plant Failed Part Analysis Report (See Figure 3) is sent to the responsible Reliability Failure Analysis Engineer.

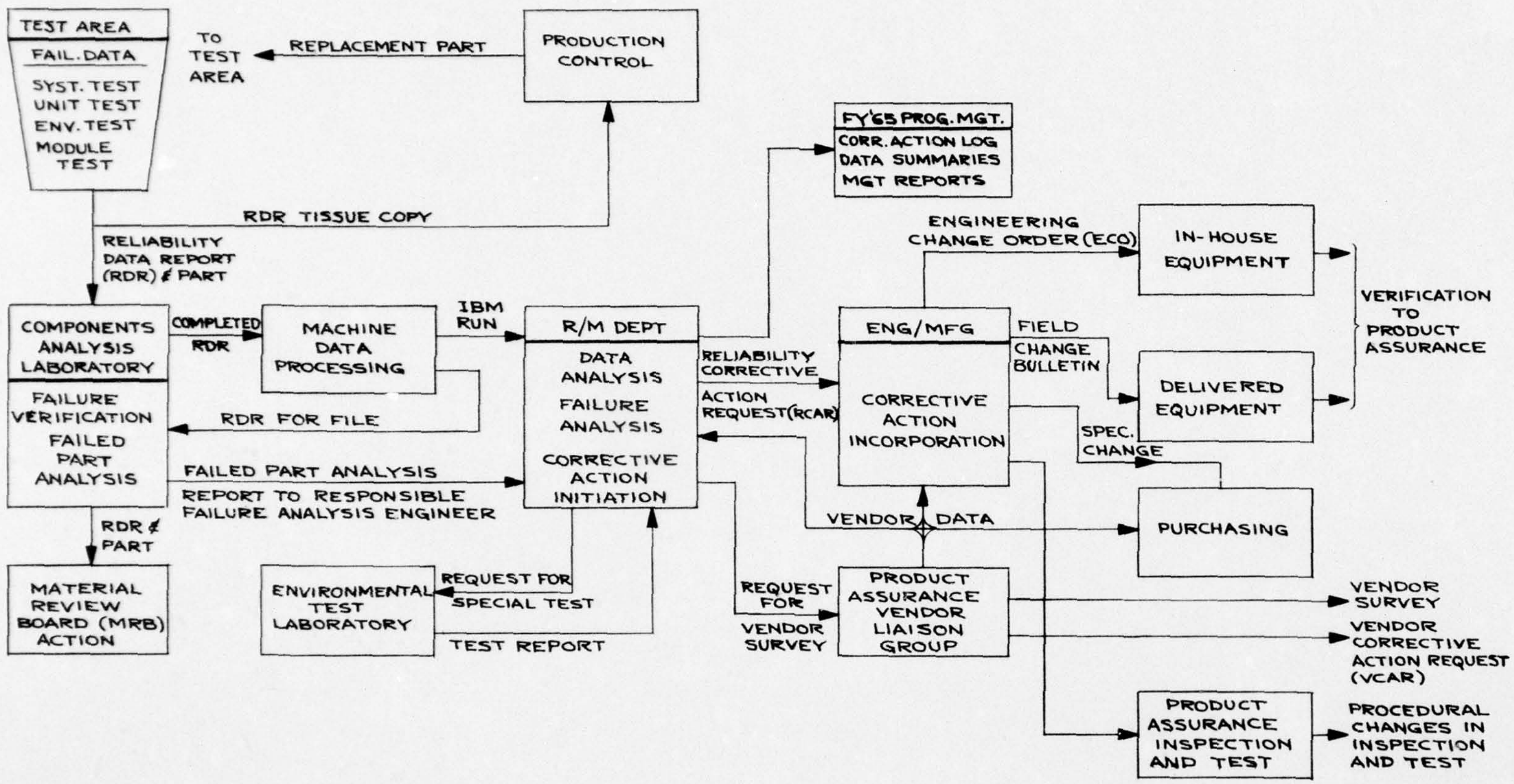


FIGURE 1 IN-PLANT FAILURE ANALYSIS FLOW CHART

RAYTHEON RELIABILITY DATA REPORT

| 1. DATE M/D/Y | 2. EQUIP. LOCATION | 3. ☐ AN/BQS-6 ☐ OTHER ____ | 4. SYSTEM SERIAL NO. | 5. FAILED ITEM NAME | 6. FAILED PART NO. |
|---|---|---|---|---|---|
| 7. SCHEMATIC/REVISION DWG. NO. | | 8. TEST PROCEDURE NO. ____ PARAGRAPH NO. ____ | 9. COMPLETE REFERENCE SYMBOL DES. | 10. OPERATING MODE ☐ ACTIVE ☐ PASSIVE | 11. NEXT ASSY. STORES |

12. FIRST INDICATION OF TROUBLE
01 ☐ INOPERATIVE
02 ☐ INTERMITTENT
03 ☐ PERFORM DEGRADED
07 ☐ OVERHEAT
26 ☐ BLOWN FUSES
41 ☐ VISUAL INSPECTION
45 ☐ POOR REGULATION
☐ OTHER (EXPLAIN)
____
____
____
☐ PROCEDURAL ERROR
(EXPLAIN) ____
____
____

13. DESCRIPTION OF FAILURE
007 ☐ ARCING
744 ☐ BINDING
070 ☐ BROKEN
739 ☐ BETA LOW
720 ☐ BRUSH FAILURE
080 ☐ BURNED OUT
819 ☐ CONTACTS DO NOT OPEN/CLOSE
320 ☐ FAILED HI-POT TEST
053 ☐ FAILS TO ZERO
003 ☐ FILAMENT OPEN
741 ☐ BACK RES. LOW
901 ☐ INTERMITTENT
380 ☐ LEAKAGE
088 ☐ GAIN, LOW
340 ☐ INSTALLED, IMPROPERLY
350 ☐ INSULATION BREAKD.
008 ☐ NOISY
450 ☐ OPEN
567 ☐ RES HIGH
568 ☐ RES LOW
006 ☐ SHORTED
737 ☐ OPEN, BASE TO COLL.
735 ☐ OPEN, BASE TO EMIT.
736 ☐ SHORT, BASE TO EMIT.
738 ☐ SHORT, BASE TO COLL.
530 ☐ POLARITY REVERSED
731 ☐ SHORTED, COLL. TO EMIT.
099 ☐ OTHER (EXPLAIN)
____
____
____
____

14. DEFECT DISCOVERED
1 ☐ MODULE TEST
2 ☐ CHASSIS TEST
3 ☐ UNIT TEST
4. ☐ SYSTEM TEST
5 ☐ ____

15. DOWN TIME
____ HRS. TROUBLE SHOOT
____ HRS. OBTAIN PART
____ HRS. REPL. PART
____ HRS. CHECK OUT

16. REPORTED BY

17. SUPERVISOR APPROVAL

18. PART DISPOSITION (TO BE FILLED IN BY E.T.L. ONLY)
☐ SCRAP
☐ RETURN TO PRODUCTION
☐ REPAIR/RE-INSTALL
☐ RETURN TO VENDOR
FAILED IN PLANT PART ANALYSIS REPORT
NO. ____

19. MATERIAL REVIEW BOARD ACTION (TO BE COMPLETED MRC ONLY)
☐ MRR NO. ____
☐ PRT NO. ____

FIGURE 2 RELIABILITY DATA REPORT FORM

RAYTHEON
SUBMARINE SIGNAL DIVISION

# FAILED IN-PLANT PART ANALYSIS REPORT

NO. ______

RDR NO. ______ DATE: ______

RAYTHEON PART NO. ______ PART DESCRIPTION ______

UNIT NO. ______ SUBASSEMBLY NO. ______

MANUFACTURER ______ MFGR'S DATE CODE ______

REJECTION CODE RDR ______

FAILED PART ANALYSIS: ______

DATE: ______ SIGNATURE ______

REMARKS: ______

DATE: ______ SIGNATURE ______

☐ PRIMARY FAILURE
☐ SECONDARY FAILURE
☐ VENDOR Q.A. PROBLEM
☐ MISAPPLICATION

☐ INDUCED FAILURE
☐ Test
☐ Mfgr.
☐ Insp.

(TO BE COMPLETED BY LAB. PERSONNEL)

80-0252

FIGURE 3 IN-PLANT FAILED PART ANALYSIS REPORT

The Reliability Failure Analysis Engineer is assigned specific failures for analysis and resolution, and is responsible for assuring that these analyses are complete, technically correct, and that corrective action is taken where necessary. The Environmental Test Laboratory and the Components Analysis Laboratory assist the failure analyst by performing part and assembly tear-down, special chemical, metallurgical and microscopic tests, environmental tests, and new-part and material evaluation. During the course of his investigation, the failure analyst might perform any or all of the following tasks:

1. Review of part specification requirements;
2. Review of circuit parameters and stresses;
3. Review of part application;
4. Review of part previous failure history;
5. Request special environmental tests;
6. Request that a vendor survey be made; and
7. Review inspection and test requirements.

The results of the analyist's investigation are documented on the reverse side of the In-Plant Failed Part Analysis Report. Thus, all essential technical data related to one specific investigation are retained in a single data package (see Figure 4).

Aids to the analyst in this work are the periodic and cumulative failure data run-offs which are prepared by the Data Processing Group. These run-offs contain failure information sorted by unit (reference designation) and by Raytheon part number. The data is processed to indicate frequency distribution of failures, to isolate possibly significant or critical failure groupings, to validate part and system reliability estimates, and to assess the effectiveness of design and procedural modifications which are initiated to reduce failure frequency. Failure information is disseminated throughout the Division so that all production and support departments are aware of part failures and of design or procedural problems which effect their operations. This specifically includes Manufacturing, Engineering, Purchasing, and the various Product Assurance functions.

RAYTHEON
SUBMARINE SIGNAL DIVISION

# OVERALL SYSTEMS EFFECT OF FAILURE

☐ ACTIVE MODE

☐ PASSIVE MODE

☐ REDUCED CAPABILITY

☐ FAILURE

☐ NEGLIGIBLE

RESULTS OF CIRCUIT ANALYSIS & CONCLUSIONS ____________________

RELIABILITY RECOMMENDATION: ____________________

CORRECTIVE ACTION:

☐ RCAR NO. __________

☐ ECO NO. __________

☐ ECR NO. __________

☐ VCA NO. __________

☐ RMM NO. __________

☐ MRB ACTION __________

☐ Scrap

☐ Use as is

☐ Rework

DATE ______ SIGNATURE __________

(TO BE COMPLETED BY RFA ENGINEER)

80-0252

FIGURE 4 IN-PLANT F.P.A. REPORT

Studies of recorded repair times also will be made to determine areas in which maintainability should be improved. Such analysis might result in recommendations for part relocations, improved packaging, improved wiring routes, etc..

A meaningful failure analysis program must include procedures for effecting timely corrective action. Date collection and analysis is a means, not an end. Raytheon Sub Sig Div has developed practical corrective action procedures which assure that:

1) Timely corrective action is taken
2) Accurate and complete records of corrective action are maintained.

This corrective action proceedure uses the standard Engineering Change form, which is called a Reliability Corrective Action Request (RCAR), when it is initiated by Reliability Engineers as a direct responsibility of failure Analysis (see Figure 5).

An original RCAR and two copies are initiated, dated and assigned a particular order number; one copy is retained by the originator for file and follow-up and two copies are sent to the responsible project engineer. At this stage, the RCAR contains a statement of the problem and the Reliability corrective action recommendations. The Project Engineer now reviews this request with the appropriate engineering activity. For example, design deficiencies are reviewed with Design Engineering, systems deficiencies are reviewed with Systems Engineering, etc. The resultant corrective actions are then noted by the Project Engineer on the RCAR under the title of <u>Action To Be Taken</u> and a copy with this information is returned to Reliability. Additional copies are routed to the Raytheon Floor Change Team of which Reliability is a member, where effectivity is established and final signature approval is obtained. The RCAR now becomes an Engineering Change Order (ECO) and the mandatory corrective action loop is closed.

In order to preclude the possibility of shipping systems or equipments having outstanding RCAR's, the Reliability Department uses an URGENT discrepancy report. This report, (Figure 6) is distributed to Quality Control Engineering, Design Engineering, i.e. (cognizant design engineer), Inspection Purchasing and Material Control requiring that a HOLD be imposed on equipment ready for shipment until final disposition is obtained. This action assures that equipment having unresolved problem areas cannot be shipped until satisfactory resolution has been obtained.

RAYTHEON SSD 80-0141 REV. A **ENGINEERING CHANGE 1** ECO DIST PAGE OF

| PART-ASSEMBLY-DOCUMENT | EQUIPMENT | REQUEST OR RCAR | | ORDER NO. |
|---|---|---|---|---|
| | | DATE | NO. | |
| | | | | ISSUE DATE |
| ORIGINATED BY- DEPT | ENG. DSO | | | |

STATEMENT OF PROBLEM - RECOMMENDATIONS - ACTION TO BE TAKEN

| ITEM NO. | PRINT DIST. | DOCUMENT NO. / MFG. BREAK-IN POINT | REVISION OLD / NEW / UNIT NO. | DISCRIPTION OF CHANGE (FROM-TO) | DISP. CODE |
|---|---|---|---|---|---|

| USAGE CONTRACT | NO. SYS | ENG. SERIAL NO. EFFECTIVITY FROM | THRU | TECH. PUB. | PROJECT APPROVAL | MFG. BREAK-IN POINT | TYPE CHANGE |
|---|---|---|---|---|---|---|---|
| | | | | | | ☐ SAME AS ENG | 1. COST RED |
| | | | | | | ☐ SEE EACH ITEM | 2. CUST ORIG |
| | | | | | | | 3. DES MOD |
| | | | | | | RECOM. FIELD RETRO YES NO | 4. DOC COR |
| | | | | | | | 5. GP HDWRE |
| | | | | | | SPARES AFFECTED YES NO | 6. PROD IMP |
| | | | | | | | 7. RELEASE |
| | | | | | | | 8. SPARES |

| DOC ATTACH | OM COST PER | REC CHGE IN SCOPE YES NO |
|---|---|---|

| CHANGE APPROVALS - SIGNATURE & DATE | | | DISP. CODE |
|---|---|---|---|
| ECO WRITTEN BY | | REL ENG | 1. NOT USABLE |
| ECO CHECKED BY | | QC ENG | 2. REWORK |
| FCT: | COMP ENG | SPARES | 3. USE AS IS |
| ENG | ELEC. ENG | SYSTEMS | 4. DOC CHGE |
| MFG | MECH. ENG | WIRING | 5. CHGE IN QTY |
| PA | MANUFAC'G | | 6. NEW PART |
| | NOMENCLATURE | CUSTOMER | |

FIGURE 5 ENGINEERING CHANGE ORDER

# URGENT

RAYTHEON
SUBMARINE SIGNAL DIVISION

## DISCREPANCY REPORT

DATE ______________ NO. ______________

NOTED BY ______________ DEPT. NO. ______________

PART NAME ______________ REF. DESIG. ______________

RAYTHEON P/N ______________ CONTRACT NO. ______________

DESCRIPTION OF MALFUNCTION OR FAILURE, AND RECOMMENDED DISPOSITION

FINAL DISPOSITION, IN HOUSE:

RECOMMENDED DISPOSITION, FIELD:

VENDOR ______________

TOTAL QUANTITY AFFECTED ______________ P.O. NO. ______________

DISTRIBUTION: RELIABILITY (2) QUALITY CONTROL ENGINEERING (1) INSPECTION (2)
COGNIZANT DESIGN ENGINEER (1) PURCHASING (2) MATERIAL CONTROL (2)

80-0225

FIGURE 6 DISCREPANCY REPORT

## n. TEST AND DOCUMENTATION

This section describes the tests to be performed on the AN/BQQ-1 Integrated Sonar System to demonstrate compliance with the dependability requirements. The demonstration testing will be performed in two phases, with dependability derived from the cumulative equipment hours.

### Demonstration Test Phase I

Phase I demonstration will be in accordance with the Life Demonstration Test plan as follows:

#### 1.0 SCOPE

A demonstration Test will be performed on a Service Test Model of the AN/BQQ-1( ) Integrated Sonar System in accordance with requirements of Contract NObsr 93138 Task "C" Paragraph 4.3.5. The purpose of this test is to evaluate the performance of a complete Sonar System configured from Retrofit III hardware in combination with equipment similar to the AN/BQQ-1B Integrated Sonar System. The results of this demonstration test will be applied as improvements to production equipment of the AN/BQQ-1 ( ) [redacted].

## 2.0 APPLICABLE DOCUMENTS

The following documents of issue in effect at the date of contract will be applicable to the extent specified.

1. MIL - S - 22974
2. MIL - S - 22732
3. Raytheon Test Procedure

## 3.0 TEST PROGRAM

The demonstration test will be conducted as follows:

An in-plant system test will be performed with the transmitter operating into a test fixture or dummy load. The equipment grouping will approximate that in an actual submarine installation as nearly as is practicable. The purpose of this is to demonstrate the life capabilities of a retrofitted system as a worst case condition. An active mode of the system will be demonstrated concurrently with a passive mode, with other modes being tested for operability. The test procedure employed will be essentially the same as used on a prior BQQ-1 test (BQS - 6A Ser. # B-4 dated Sept. 1964). At the conclusion of this demonstration test a decision will be made by BuShips Code 1632 as to any additional testing requirements to be applied to the production systems.

The detailed test procedure for the demonstration test will be prepared by Raytheon SSD and submitted for preliminary approval to the Underwater Sound Laboratory prior to submission to BuShips for final approval. Bureau or Agency approval will be obtained prior to setting up test equipment.

## 4.0 TEST ENVIRONMENT

The testing of the equipment will be carried out in the following environment:

| | |
|---|---|
| Temperature | 25° ± 5° C (68° to 86°F) |
| Vibration | ± 1 G at any non-resonant frequency between 20 and 60 c. p. s. measured at the equipment mounting points. Duration of vibration will be at least 15% of total test time (approximately 10 minutes per operating hour). Vibration technique will be in accordance with paragraph 4. 2. 3. 1. 2. of MIL -R-22732. |
| Heating/Cooling Cycles | The equipment will be exposed to the upper half of the temperature limit at least 50% of the test time. |
| Input Voltage | Nominal. |
| Test Operating Cycle | 3 1/2 hours operating, 1/2 hour off. |

## 5.0 FAILURE CRITERIA

A system failure will be charged if the performance of the system degrades below the value specified in Table I of the Dependability Supplement for the particular operating mode, or if a failure occurs in a series circuit that prevents performance of the designed function for the mode. However, a system failure will not be charged if the malfunction can be corrected by demonstration of adequate performance of the required function using an alternate equipment configuration. All malfunctions will be recorded with the resulting quantitative degradation. If the malfunction is repaired, an assessment will be made to determine if the cumulative degradation results in out-of-specification performance.

Failures are classified as either relevant or non-relevant . Only relevant failures shall be counted in the computation of the demonstrated MTBF.

RELEVANT FAILURES

Relevant failures are those failures attributed to:

(1) Design defects

(2) Manufacturing defects

(3) Parts defects, including missing or wrong parts

(4) Unknown cause

(5) Random sources

NON-RELEVANT FAILURES

Non-relevant failures are those failures attributed to:

(1) Accidents or mishandling

(2) Operator error

(3) Installation error

(4) Dependent failure

(5) Test or monitoring equipment failure (if not built in test equipment)

(6) Maintenance

Recurring failure events resulting from the same cause shall be chargeable only once as a relevant failure. It must positively show that the failures are due to the same cause before they are to be classified as recurring events.

## 6.0 ACCEPT/REJECT CRITERIA

The following accept/reject criteria apply:

The system will be operated in an active mode for the maximum time available, after suitable burn-in, that will be consistent with the proposed delivery schedule of 1 April 1967. If at the end of this time suitable reliability has not been demonstrated, or when more than 13 failures have occurred, Raytheon SSD will provide all test failure data to the Bureau of Ships Code 1632 will provide all test and failure data to the Bureau of Ships Code 1632 for a decision as to accept, reject, continue testing the system or perform testing on other systems.

The system shall be operated concurrently in the Passive Detection mode of operation for the same time. If at the end of this time, suitable reliability has not been demonstrated, Raytheon SSD will provide all test and failure data to the Bureau of Ships Code 1632 for a decision as to accept, reject, continue testing the system or perform testing on other systems.

### FAILURE CRITERIA PASSIVE MODE

A. NOT ACCEPTABLE

(1) Seven failures of any type

B. ACCEPTABLE

(1) Three or less failures

(2) Six or less failures, provided that three or less are random and the Bureau of Ships Code 1632 approves corrective action.

C. NEGOTIABLE

(1) Six or less failures, provided more than three are random.

SYSTEM ACTIVATION TEST

The system will undergo test cycles from Active Listen to Transmit condition. Failure to operate after activation shall be a cyclic failure. Acceptance criteria are given in the following table:

| NO. OF CYCLES | ALLOWANCE FAILURES |
|---|---|
| 230 | 0 |
| 390 | 1 |
| 530 | 2 |
| 643 | 3 |
| 790 | 4 |
| 915 | 5 |
| 1025 | 6 |

7.0 RECORDS AND REPORTS

Records and reports will be in accordance with the requirements of MIL - R-22732. A Final Report will be submitted 30 days after completion of testing.

8.0 MAINTAINABILITY

All maintenance and repair actions will be monitored during this demonstration test.

Demonstration Test Plan - Phase II

Phase II Demonstration Test will be applied to the AN/BQS - 6 ( ) Production equipments Serial #2 and #3 for the purpose of accumulating sufficient operating time to assure adequate confidence in demonstrated dependability. The conditions for test as well as the Accept/Reject Criteria will be in accordance with the Dependability Supplement. The detailed test procedure will be submitted to Underwater Sound Laboratories for preliminary approval, and to the Bureau of Ships at least 60 days prior to the start of testing. The system will be operated after a suitable burn-in using a configuration approximating submarine installation as closely as is practical. These tests will be performed at the Raytheon facilities. A final report will be provided at the conclusion of each phase of testing in accordance with MIL - R- 22732.

o. PROGRAM REVIEW AND REPORTS (Figure1)

1. Periodic Review of Program

The overall Dependability Program status will be determined from periodic correlation of individual task status reports, required from activity group leaders. Continual updating of the program PERT charts will reflect the trade-offs of assignments and achievements. This process of progressive evaluation will be applied throughout the program.

2. Quarterly Progress Reports

The program status including progress on the various Dependability Program Activities will b e reported in Quarterly Progress Reports to the Program Manager. The Quarterly Progress Reports will include the current PERT scheduling and will be submitted to the customer within thirty ( 30 ) days of the end of the reporting period.

3. R/M Design Review Final Report

At the conclusion of the Design Review effort, a comprehensive report will be submitted, detailing the Design Review effort and its accomplishments in improving the equipment reliability and maintainability . Included will be design review memos and other internal documentations, including the impact of the Critical Parts Program, the Statistical Circuit Studies, and the Failure Mode and Effects Analysis on the equipment design.

4. Life Demonstration Test Procedure and Report

The test requirements and results of the Service Test Model Life Demonstration Test will be documented and submitted in accordance with the requirements of MIL-STD - 22974, Paragraph 4. 3. 3. 3. Test data, including failure reports and analyses, will be submitted at the conclusion of testing

| | 1965 | | | | | | | | | | | | 1966 | | | | | | | | | | | | 1967 | | | | | | | | | | | | 1968 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DOCUMENT | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A |
| QUARTERLY REPORTS | | | | | | | | | | | | △ | | | △ | | | △ | | | △ | | | △ | | | △ | | | △ | | | △ | | | △ | | | | |
| R/M DESIGN REVIEW FINAL REPORT | | | | | | | | | | | | | | | | | | △ | | | | | | | | | | | | | | | | | | | | | | |
| LIFE DEMONSTRATION TEST PROCEDURE | | | | | | | | | | | | | | | | | | | | | | △ | | | | | | | | | | | | | | | | | | |
| LIFE DEMONSTRATION TEST REPORTS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | △ | | | | | | | | | | |
| MAINTAINABILITY TEST PROCEDURE | | | | | | | | | | | | | | | | | | | | | | | | | | | | △ | | | | | | | | | | | | |
| MAINTAINABILITY TEST REPORT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | △ | | | | |
| DEPENDABILITY TEST PROCEDURE | | | | | | | | | | | | | | | | | | | | | | | | | △ | | | | | | | | | | | | | | | |
| DEPENDABILITY TEST REPORT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | △ |
| PREDICTION ANALYSIS REPORT | | | △ | | | | | | | | | | △ | | | | △ | | | | | | | | | | | | | | | | | | | | | | | |
| DEPENDABILITY PROGRAM FINAL REPORT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | △ |
| FAILURE ANALYSES AND REPORTS | | | | | | | | | | | | | | | | △ | | | | | | | | | | | | | | | | | | | △ | | | | | |

FIGURE 1 TIME PHASE REPORTING CYCLE

to the procuring agency ( Bureau of Ships, Code 1632 ) for review and approval and for determination whether additional testing is required.

5. Reliability Demonstration Test Plan and Report

The test requirements and results of the Reliability Demonstration Test on the Production equipment will be documented and submitted in accordance with the requirements of MIL-S-22974, Paragraph 4.3.3.3. Test data, including failure reports and analyses, will be submitted at the conclusion of testing to the Bureau of Ships, Code 1632 for review and approval.

6. Maintainability Demonstration Test Plan and Report

The proposed Maintainability Demonstration Test Plan will be submitted in accordance with the requirements of MIL-S-22974, Paragraph 4.3.3.3. The results of the test will be submitted at the completion of testing for review and analysis by the Bureau.

7. Final Prediction Analysis Report

A Final Prediction Analysis report for the AN/BQQ-1 Sonar System will be submitted at the completion of the design phase, defining the mathematical models, the overall reliability and maintainability prediction procedures and indicating the final predicted equipment reliability. The techniques for analysis, using the prescribed operating modes, will be presented.

8. Dependability Final Report

At the completion of the program a complete and comprehensive report will be generated, indicating the efforts and achievements of the Dependability Organization in optimizing the equipment dependability. The program efforts, from the initial design phase through the Production cycle, will be presented. Where significant improvements were made as a result of the Dependability Program efforts, these will be documented. This report will summarize the overall program as applied to the AN/BQQ-1 Sonar system.